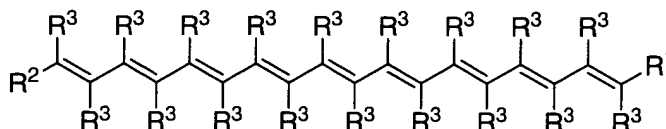


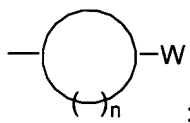
**What is claimed is:**

1. A chemical compound comprising a carotenoid derivative having the structure



where each  $R^3$  is independently hydrogen or methyl;

10 where  $R^1$  and  $R^2$  are independently an acyclic alkene comprising at least one substituent or a cyclic ring comprising at least one substituent, wherein the cyclic ring having general structure:



15 where n is 4 to 10 carbon atoms; and

where W is the substituent.

2. The compound of claim 1, wherein each of the substituents  $-W$  independently comprises  $-XR$ , wherein each X independently comprises O, N, or S.

3. The compound of claim 1, wherein each of the substituents  $-W$  independently comprises amino acids, esters, carbamates, amides, carbonates, alcohol, phosphates, or sulfonates.

4. The compound of claim 1, wherein the carotenoid derivative is at least partially water soluble.

5. The compound of claim 1, wherein the substituent is at least partially hydrophilic.

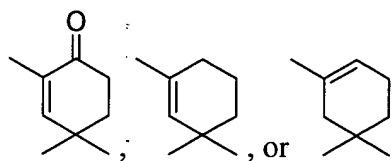
6. The compound of claim 1, wherein the cyclic ring further comprises at least one chiral center.

5 7. The compound of claim 1, wherein the substituent increases the water solubility of the compound.

8. The compound of claim 1, wherein the cyclic ring further comprises at least one degree of unsaturation.

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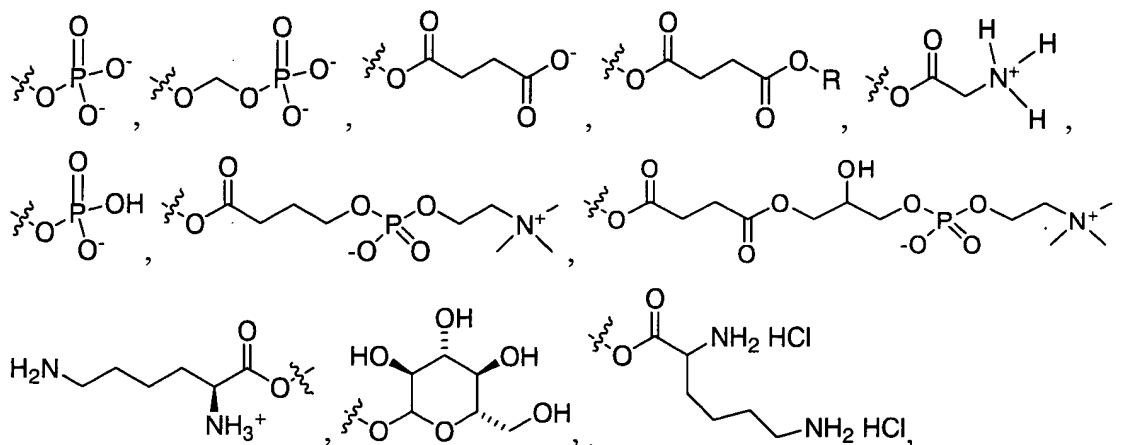
9. The compound of claim 1, wherein each cyclic ring is independently



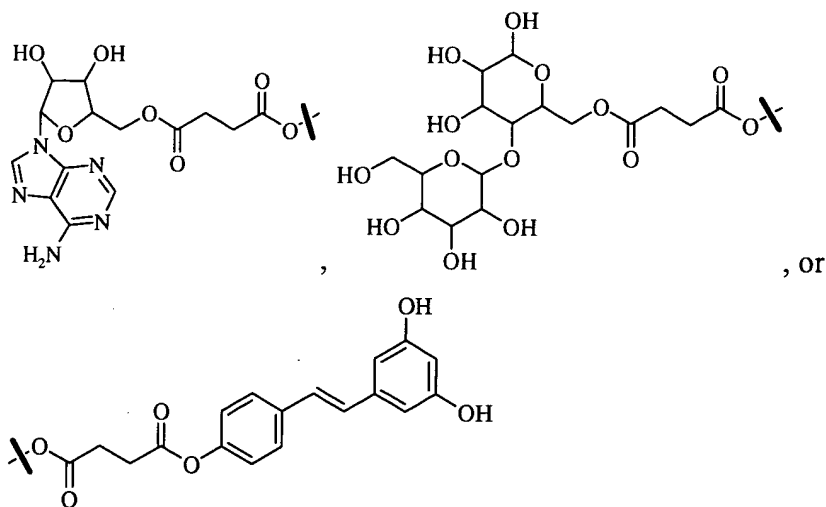
15 10. The compound of claim 1, wherein the substituent is a carboxylic acid, an ester, an alkanol, an amine, a phosphate, a succinate, a glycinate, an ether, a glucoside, a sugar, or a carboxylate salt.

11. The compound of claim 1, wherein each substituent is independently

20





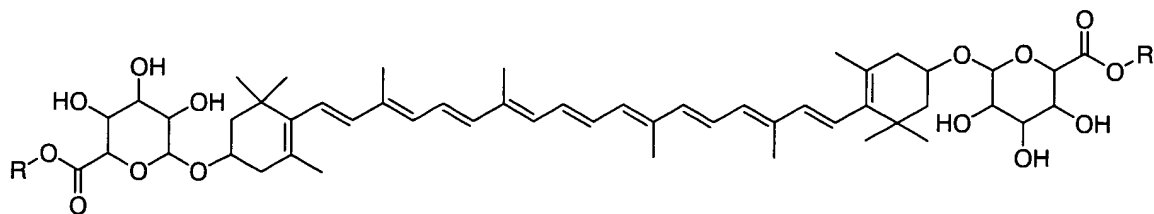


where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

12. The compound of claim 1, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid.

13. The compound of claim 1, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid, and wherein the naturally occurring carotenoid is lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or canthaxanthin.

14. The compound of claim 1, wherein the carotenoid derivative having the structure

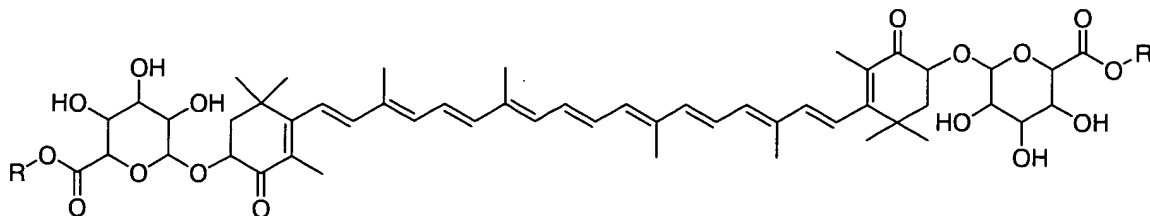


where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

Atty. Dkt. No.: 5777-00201

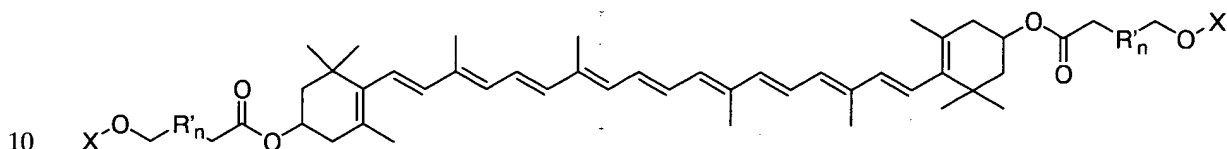
Meyertons, Hood, Kivlin,  
Kowert & Goetzl, P.C.

15. The compound of claim 1, wherein the carotenoid derivative having the structure



5 where each R is independently -alkyl-NR<sub>3</sub><sup>+</sup>, -aromatic-NR<sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

16. The compound of claim 1, wherein the carotenoid derivative having the structure

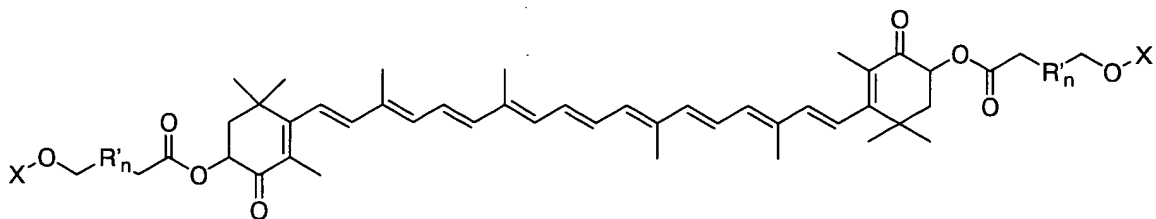


where each X is independently -alkyl-NR<sub>3</sub><sup>+</sup>, -aromatic-NR<sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

17. The compound of claim 1, wherein the carotenoid derivative having the structure

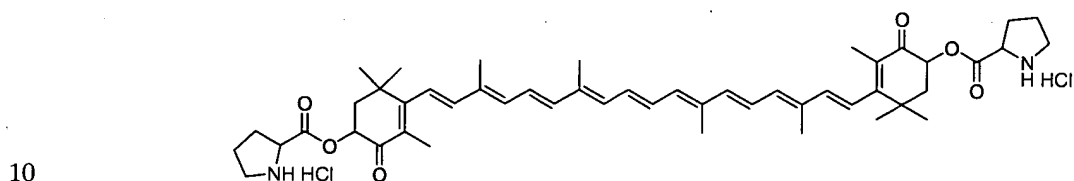


where each X is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

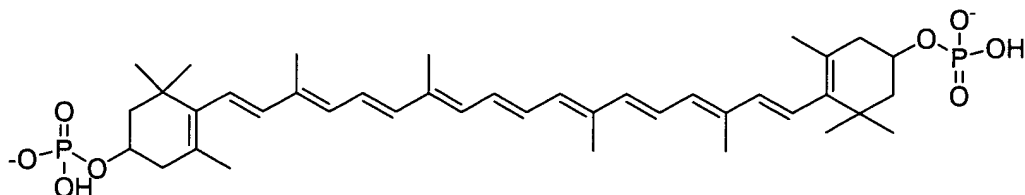
5 where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

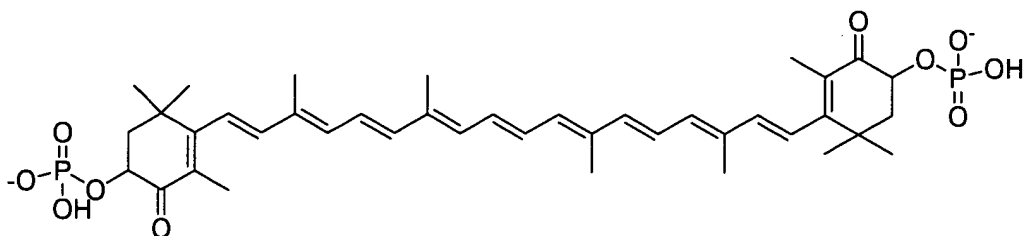
18. The compound of claim 1, wherein the carotenoid derivative having the structure



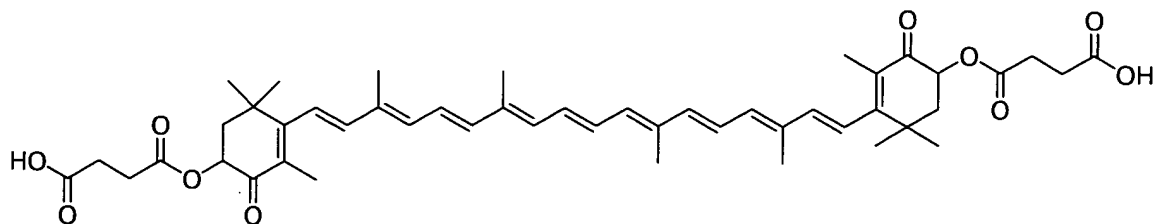
19. The compound of claim 1, wherein the carotenoid derivative having the structure



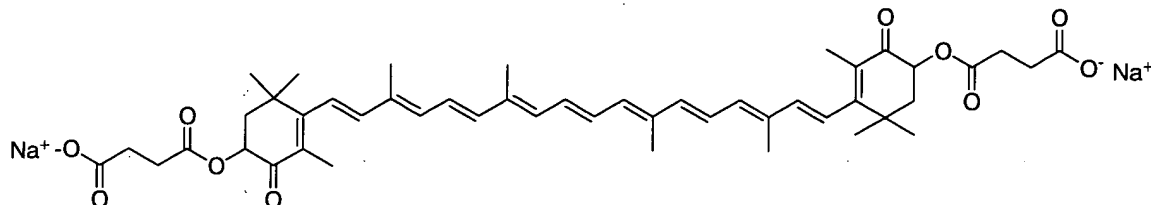
15 20. The compound of claim 1, wherein the carotenoid derivative having the structure



21. The compound of claim 1, wherein the carotenoid derivative having the structure

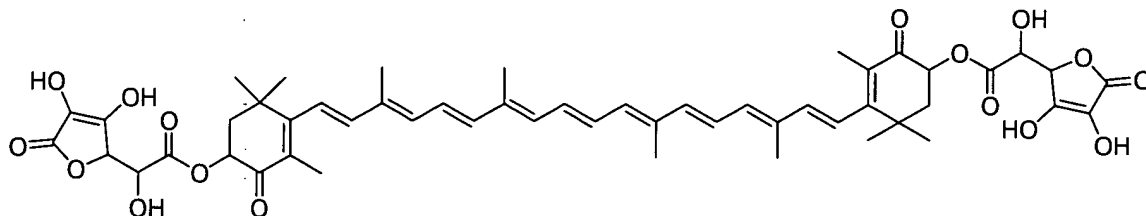


22. The compound of claim 1, wherein the carotenoid derivative having the structure

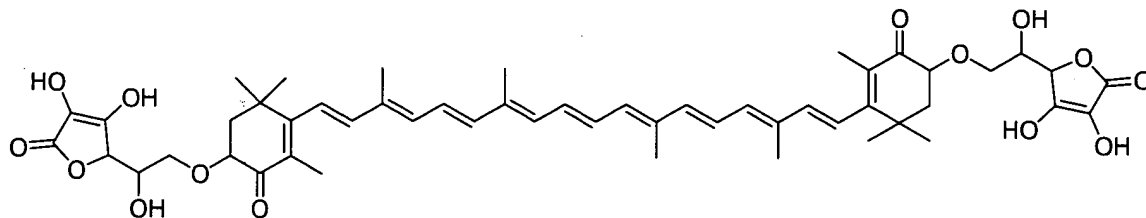


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23. The compound of claim 1, wherein the carotenoid derivative having the structure

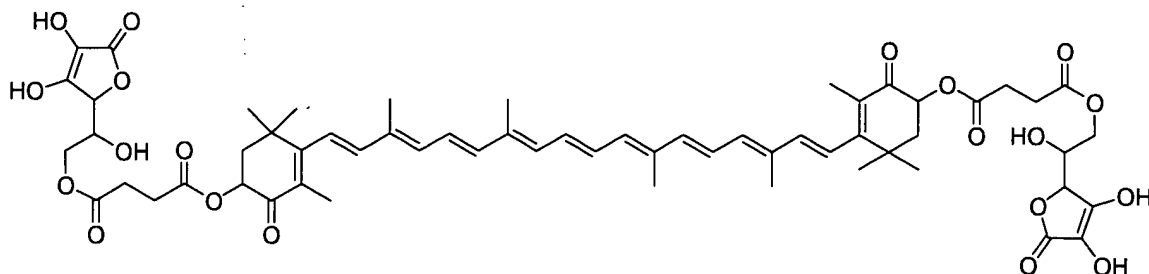


24. The compound of claim 1, wherein the carotenoid derivative having the structure

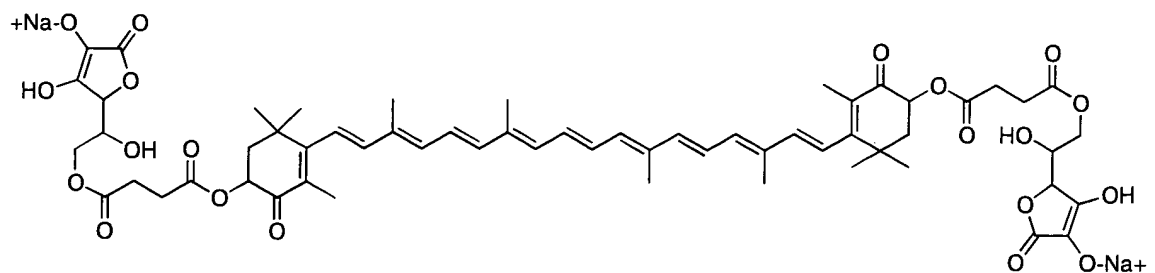


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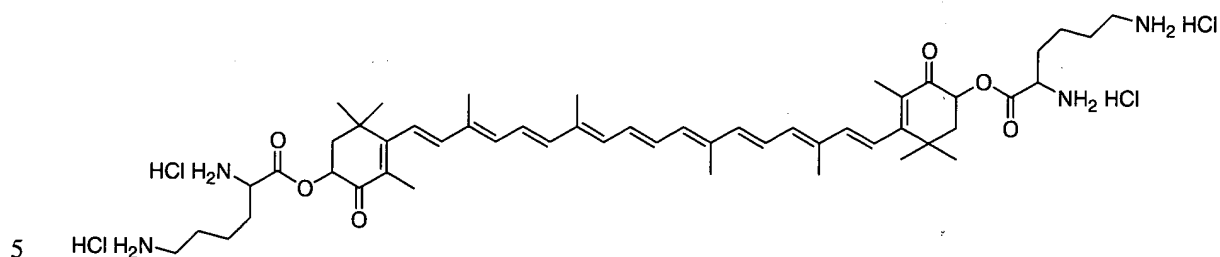
25. The compound of claim 1, wherein the carotenoid derivative having the structure



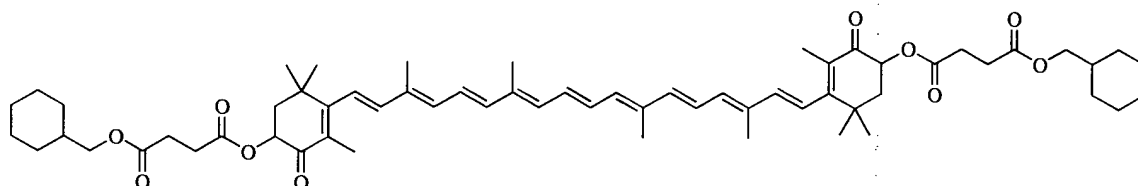
26. The compound of claim 1, wherein the carotenoid derivative having the structure



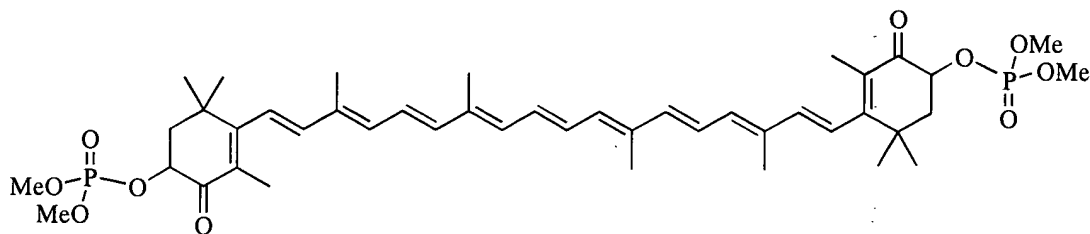
27. The compound of claim 1, wherein the carotenoid derivative having the structure



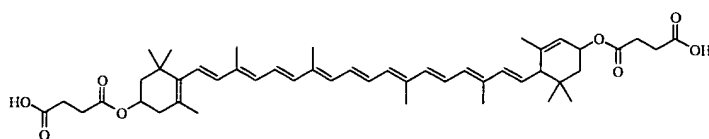
28. The compound of claim 1, wherein the carotenoid derivative having the structure



29. The compound of claim 1, wherein the carotenoid derivative having the structure



30. The compound of claim 1, wherein the carotenoid derivative having the structure





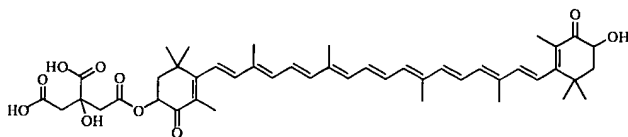
- [illegible]

- [illegible]

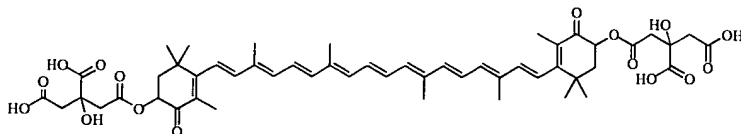
- [illegible]

- COC(=O)C(O)=CC(=O)Oc1cc(C)c(C)c(c1=O)/C=C/C(C)=C/C=C/C(C)=C/C=C/C(C)=C/C=C/C(C)=C/C=C/C(C)=C/C=C/C(C)=C/c2cc(C)c(C)c(c2=O)OC(=O)C(O)=CC(=O)O

- Atty. Dkt. No.: 5777-00201

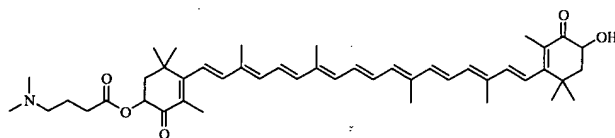


36. The compound of claim 1, wherein the carotenoid derivative having the structure

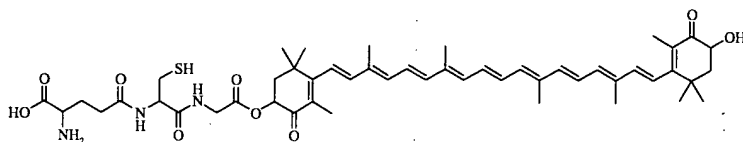


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37. The compound of claim 1, wherein the carotenoid derivative having the structure

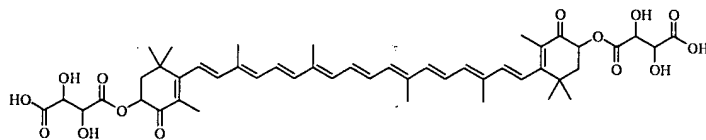


38. The compound of claim 1, wherein the carotenoid derivative having the structure

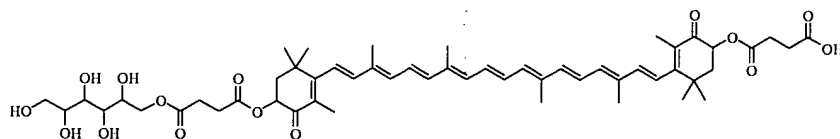


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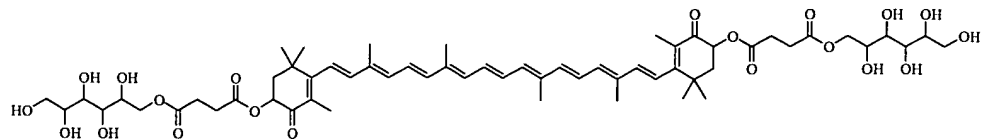
39. The compound of claim 1, wherein the carotenoid derivative having the structure



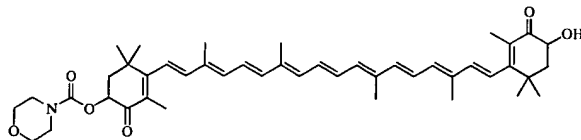
- 15 40. The compound of claim 1, wherein the carotenoid derivative having the structure



41. The compound of claim 1, wherein the carotenoid derivative having the structure

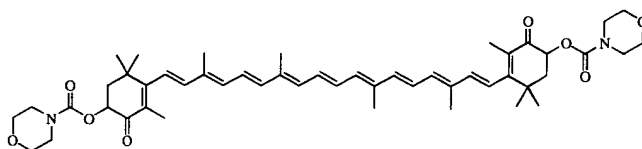


42. The compound of claim 1, wherein the carotenoid derivative having the structure

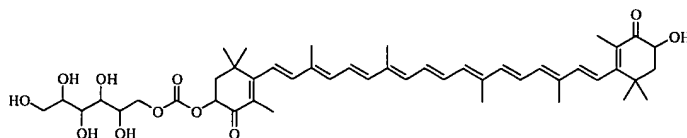


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43. The compound of claim 1, wherein the carotenoid derivative having the structure

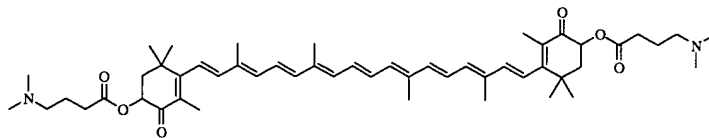


44. The compound of claim 1, wherein the carotenoid derivative having the structure



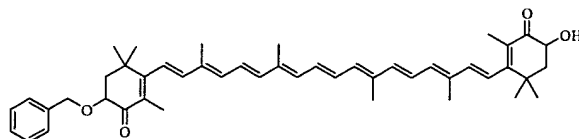
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45. The compound of claim 1, wherein the carotenoid derivative having the structure

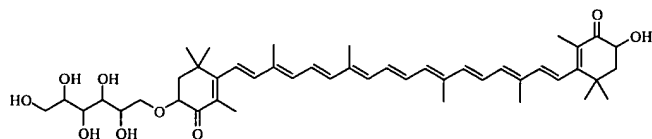


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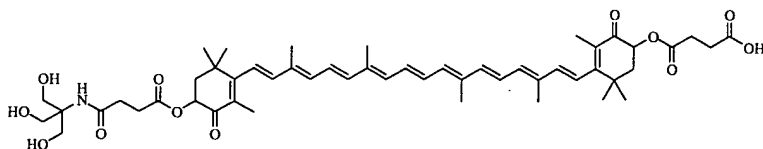
46. The compound of claim 1, wherein the carotenoid derivative having the structure



47. The compound of claim 1, wherein the carotenoid derivative having the structure

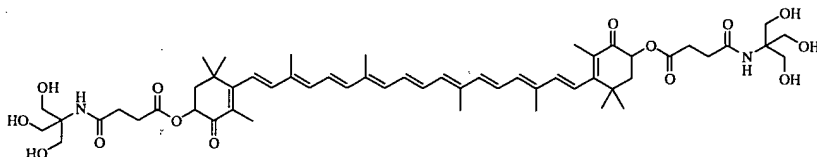


48. The compound of claim 1, wherein the carotenoid derivative having the structure

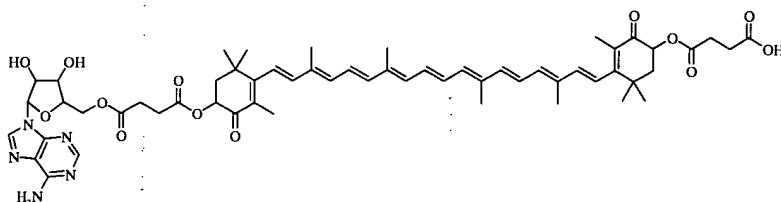


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49. The compound of claim 1, wherein the carotenoid derivative having the structure

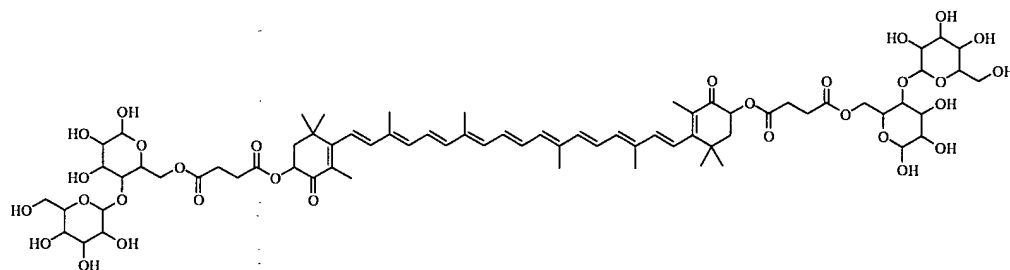


50. The compound of claim 1, wherein the carotenoid derivative having the structure

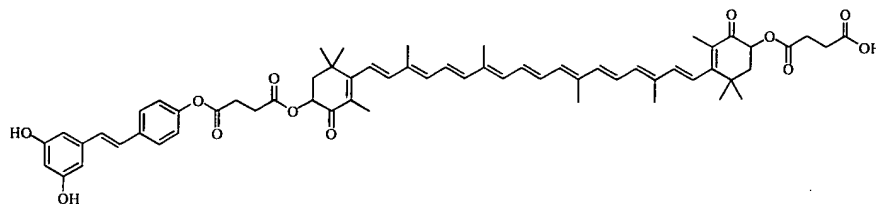


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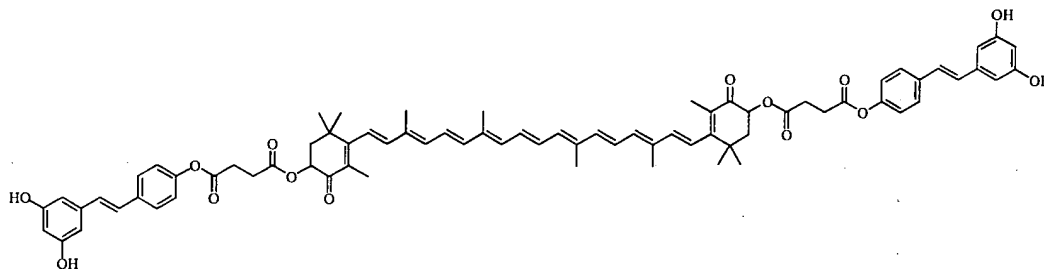
51. The compound of claim 1, wherein the carotenoid derivative having the structure



- 15 52. The compound of claim 1, wherein the carotenoid derivative having the structure

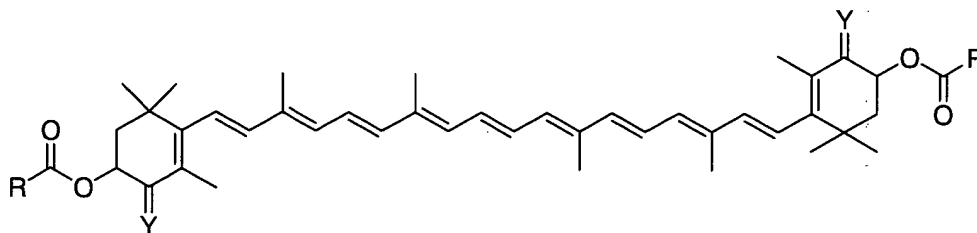


53. The compound of claim 1, wherein the carotenoid derivative having the structure



5

54. A chemical compound comprising a carotenoid derivative having the structure



10

where each Y is independently O or H<sub>2</sub>;

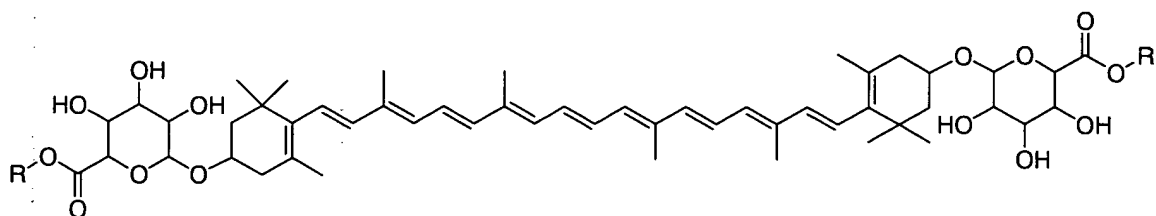
where each R is independently OR<sup>1</sup> or R<sup>1</sup>;

- 15 where each R<sup>1</sup> is independently -alkyl-NR<sub>3</sub><sup>2+</sup>, -aromatic-NR<sub>3</sub><sup>2+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

where each R<sup>2</sup> is independently H, alkyl, or aryl.

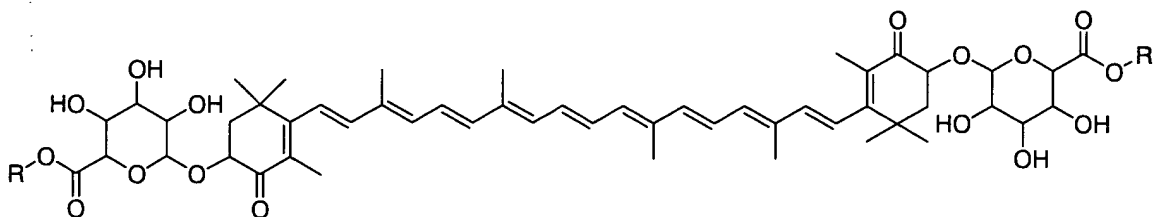
20

55. The compound of claim 54, wherein the carotenoid derivative is at least partially water soluble.
56. The compound of claim 54, wherein the cyclic ring further comprises at least one  
5 chiral center.
57. The compound of claim 54, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid.
- 10 58. The compound of claim 54, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid, and wherein the naturally occurring carotenoid is lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or canthaxanthin.
- 15 59. The compound of claim 54, wherein the carotenoid derivative having the structure



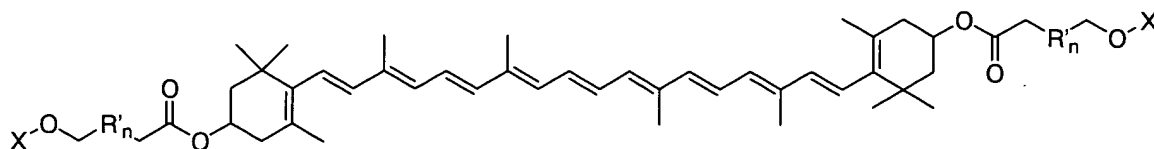
- where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
20 H, alkyl, or aryl.

60. The compound of claim 54, wherein the carotenoid derivative having the structure



where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

- 5 61. The compound of claim 54, wherein the carotenoid derivative having the structure



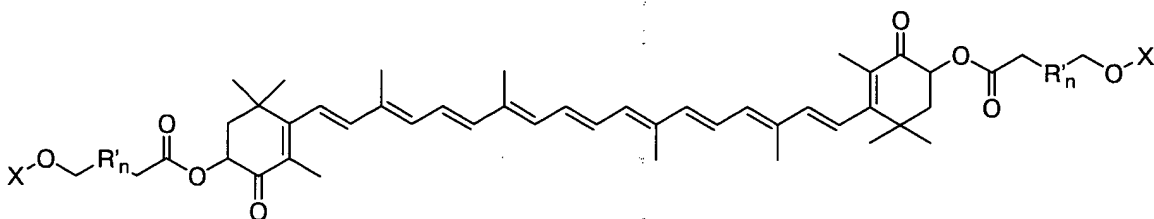
- where each X is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
10 H, alkyl, or aryl;

where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

15

62. The compound of claim 54, wherein the carotenoid derivative having the structure

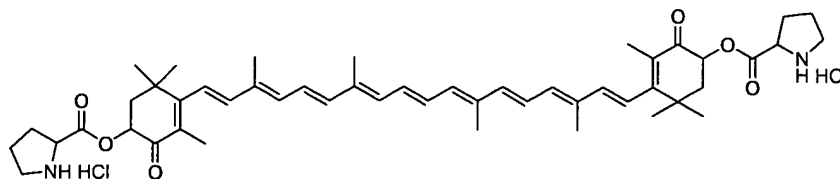


- where each X is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
20 H, alkyl, or aryl;

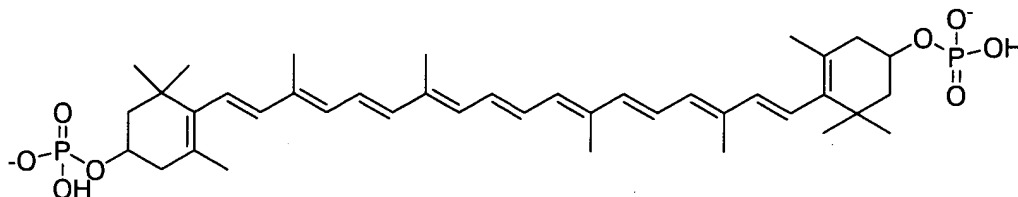
where each R' is independently -alkyl-O, alkyl, or aryl; and

- 25 where n is between about 0 and 12.

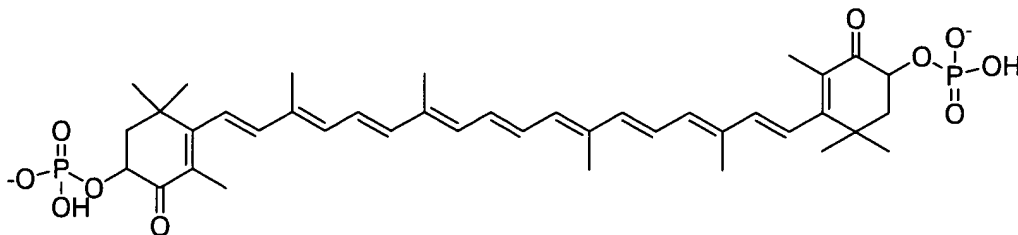
63. The compound of claim 54, wherein the carotenoid derivative having the structure



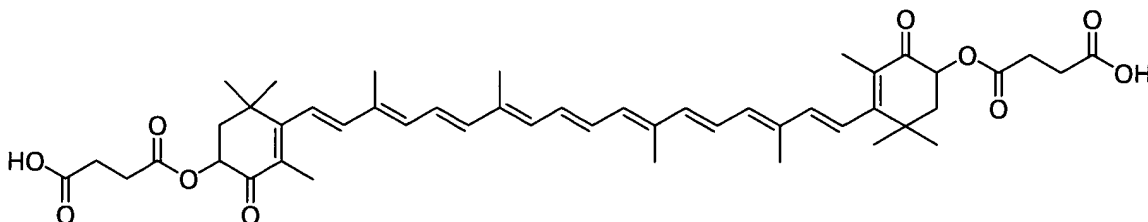
64. The compound of claim 54, wherein the carotenoid derivative having the structure



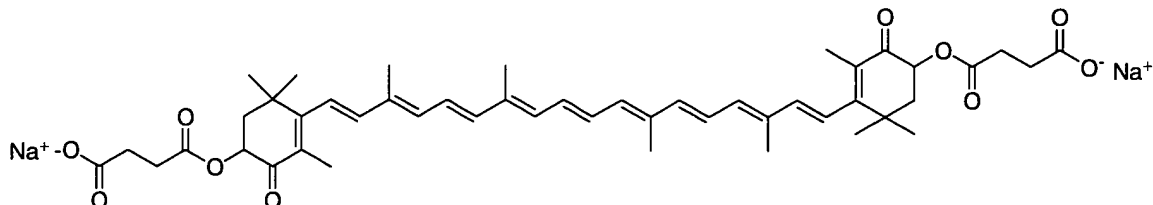
65. The compound of claim 1, wherein the carotenoid derivative having the structure



66. The compound of claim 54, wherein the carotenoid derivative having the structure

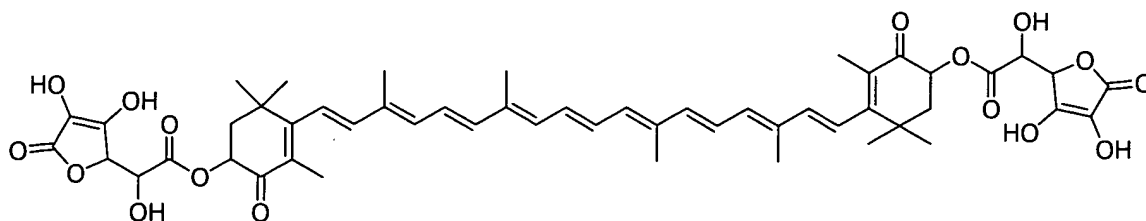


67. The compound of claim 54, wherein the carotenoid derivative having the structure

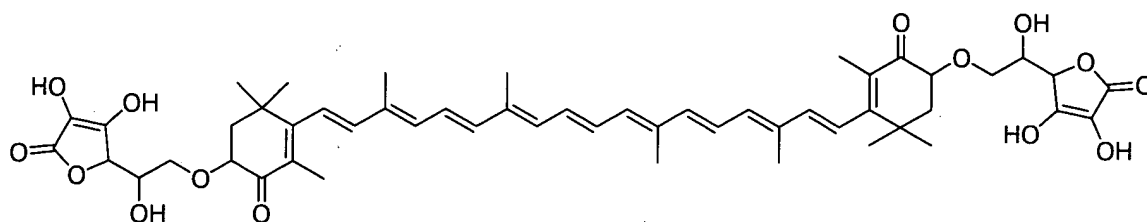




68. The compound of claim 54, wherein the carotenoid derivative having the structure

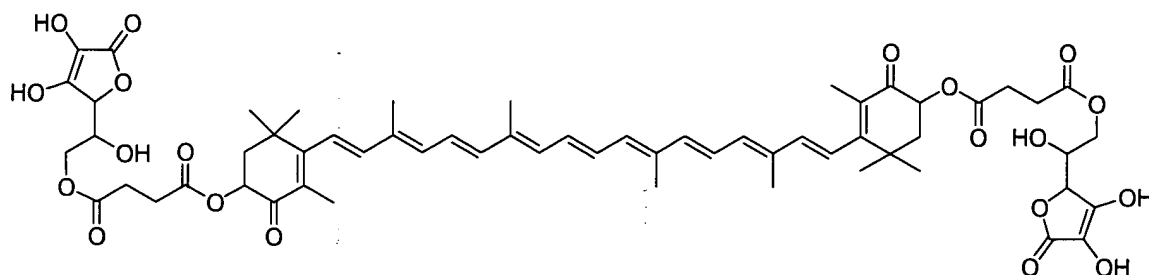


69. The compound of claim 54, wherein the carotenoid derivative having the structure

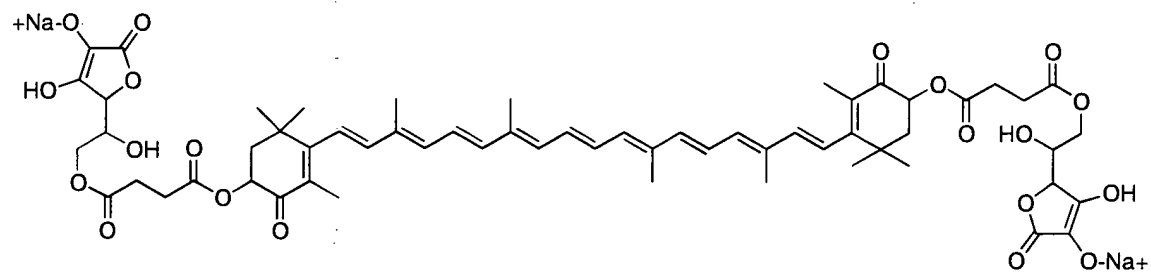


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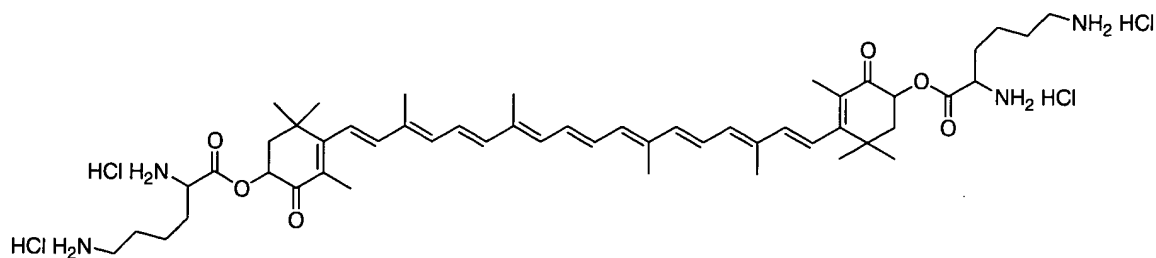
70. The compound of claim 54, wherein the carotenoid derivative having the structure



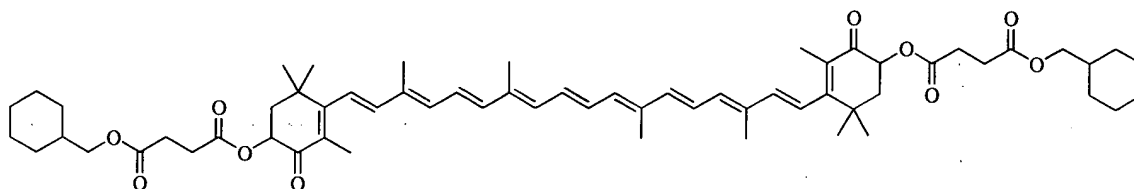
10 71. The compound of claim 54, wherein the carotenoid derivative having the structure



72. The compound of claim 54, wherein the carotenoid derivative having the structure

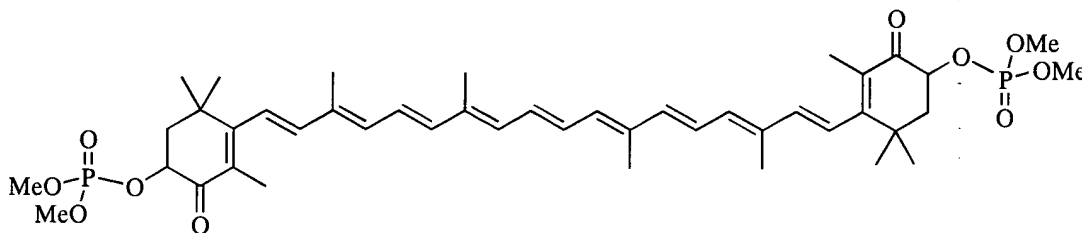


73. The compound of claim 54, wherein the carotenoid derivative having the structure

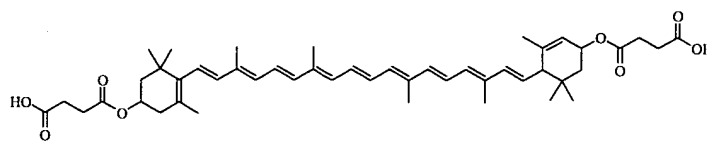


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74. The compound of claim 54, wherein the carotenoid derivative having the structure

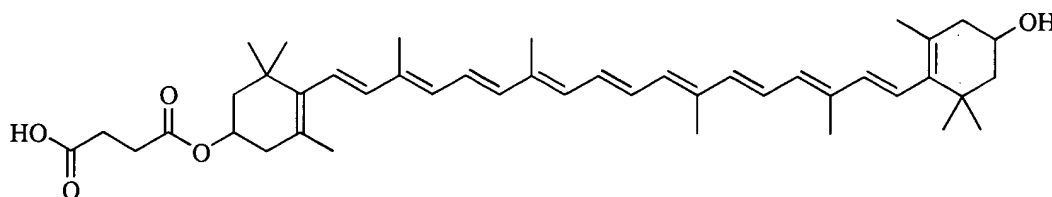


75. The compound of claim 54, wherein the carotenoid derivative having the structure

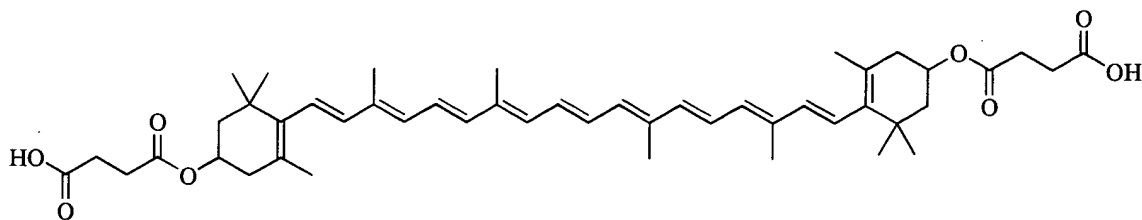


10

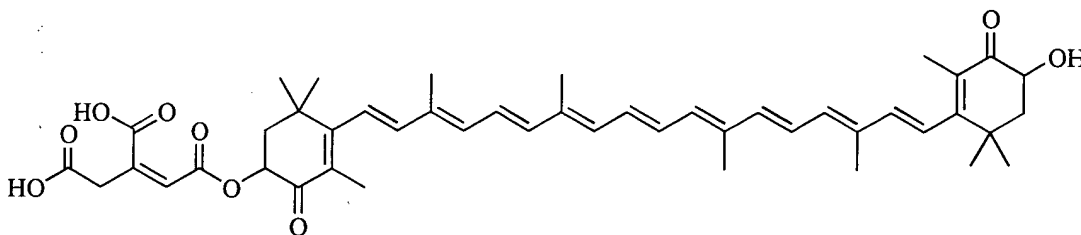
76. The compound of claim 54, wherein the carotenoid derivative having the structure



15 77. The compound of claim 54, wherein the carotenoid derivative having the structure

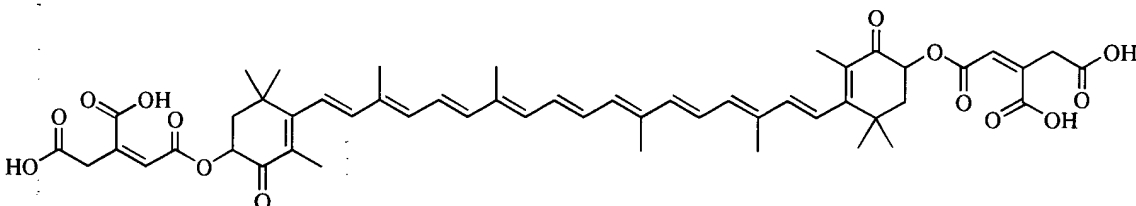


78. The compound of claim 54, wherein the carotenoid derivative having the structure

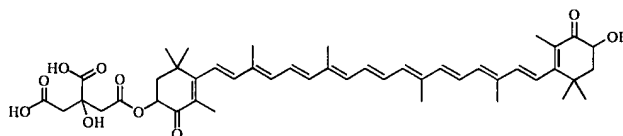


5

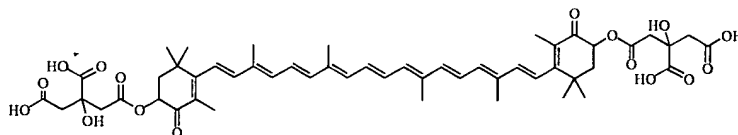
79. The compound of claim 54, wherein the carotenoid derivative having the structure



10 80. The compound of claim 54, wherein the carotenoid derivative having the structure

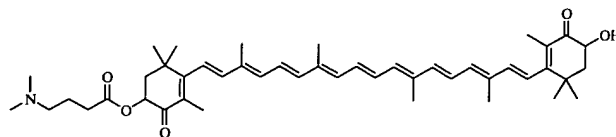


81. The compound of claim 54, wherein the carotenoid derivative having the structure

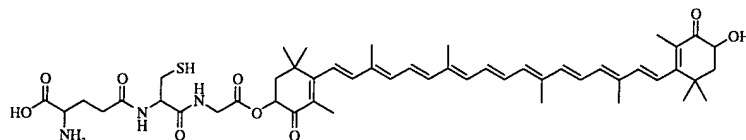


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82. The compound of claim 54, wherein the carotenoid derivative having the structure

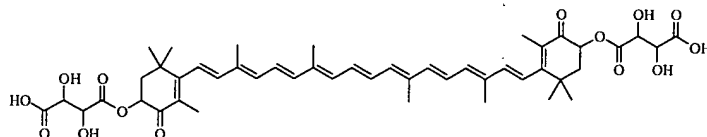


83. The compound of claim 54, wherein the carotenoid derivative having the structure

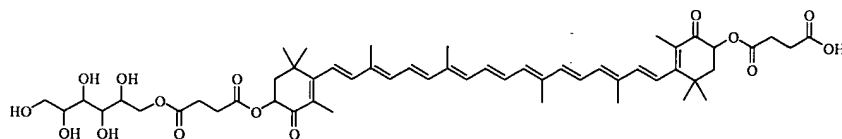


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84. The compound of claim 54, wherein the carotenoid derivative having the structure

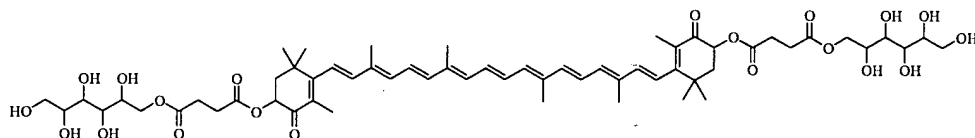


85. The compound of claim 54, wherein the carotenoid derivative having the structure

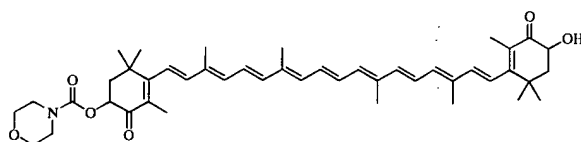


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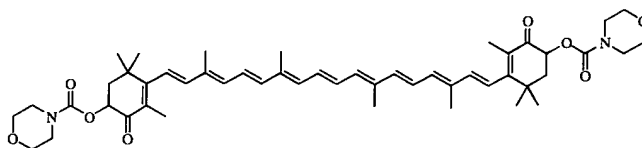
86. The compound of claim 54, wherein the carotenoid derivative having the structure



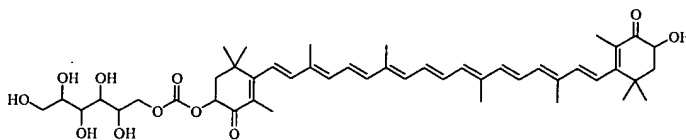
- 15 87. The compound of claim 54, wherein the carotenoid derivative having the structure



88. The compound of claim 54, wherein the carotenoid derivative having the structure

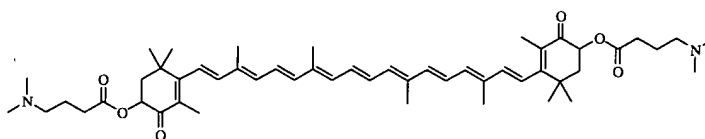


89. The compound of claim 54, wherein the carotenoid derivative having the structure

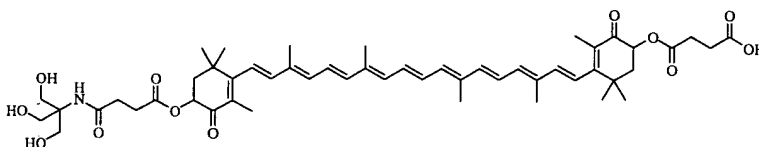


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90. The compound of claim 54, wherein the carotenoid derivative having the structure

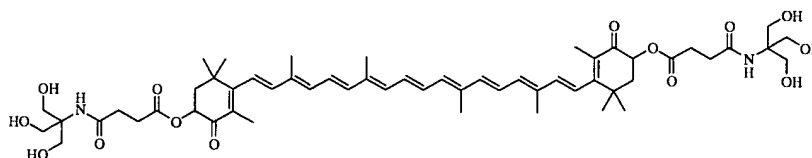


91. The compound of claim 54, wherein the carotenoid derivative having the structure



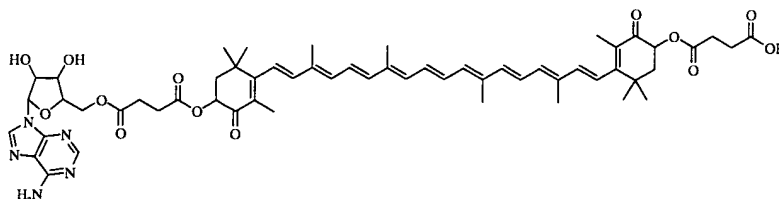
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92. The compound of claim 54, wherein the carotenoid derivative having the structure



15

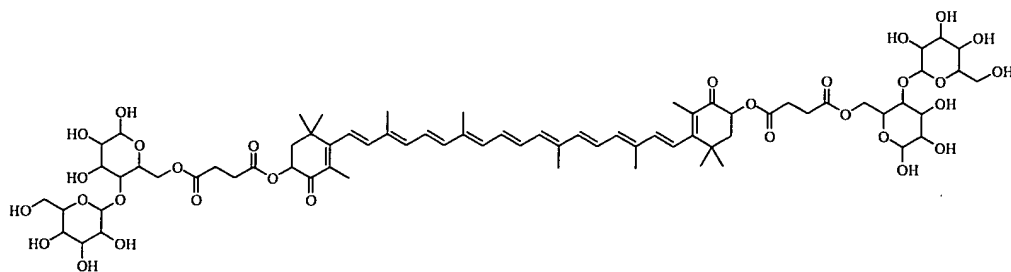
93. The compound of claim 54, wherein the carotenoid derivative having the structure



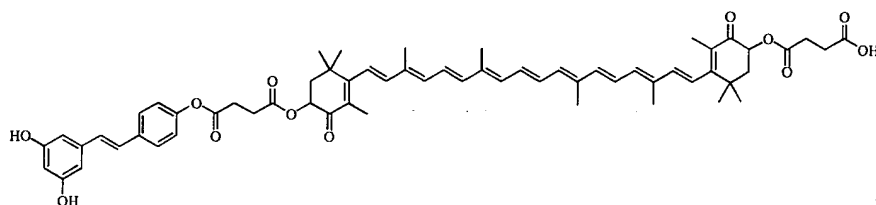
94. The compound of claim 54, wherein the carotenoid derivative having the structure

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Meyertons, Hood, Kivlin,  
Kowert & Goetzel, P.C.

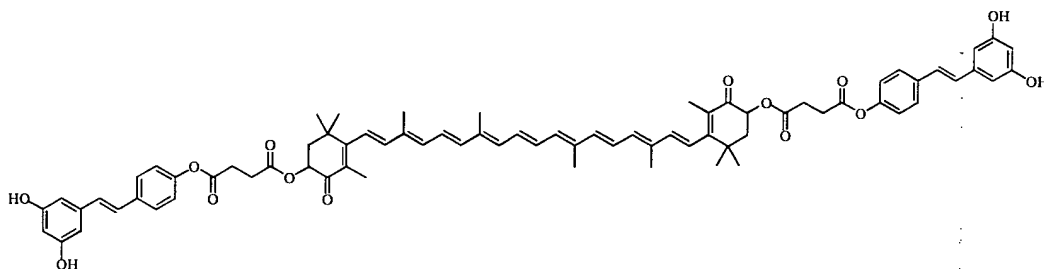


95. The compound of claim 54, wherein the carotenoid derivative having the structure



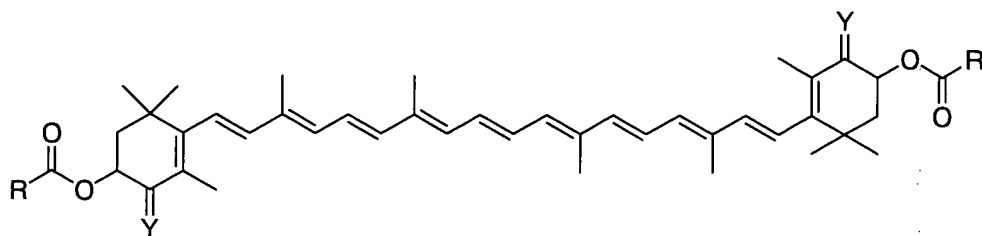
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96. The compound of claim 54, wherein the carotenoid derivative having the structure



97. A chemical compound comprising a carotenoid derivative having the structure

10



where each Y is independently O or H<sub>2</sub>;

15

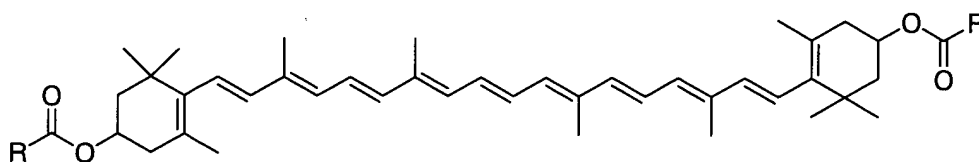
where each R is independently OR<sup>1</sup> or R<sup>1</sup>;

where each R<sup>1</sup> is independently -alkyl-NR<sub>3</sub><sup>2+</sup>, -aromatic-NR<sub>3</sub><sup>2+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

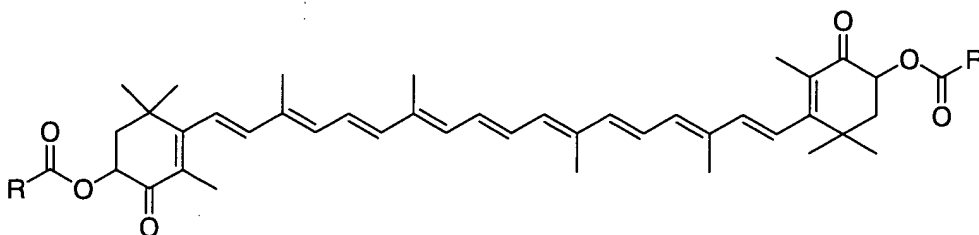
5        where each R<sup>2</sup> is independently H, alkyl, or aryl.

98.    The compound of claim 97, wherein the carotenoid derivative is at least partially water soluble.

10    99.    The compound of claim 97, wherein Y is H<sub>2</sub>, the carotenoid derivative having the structure

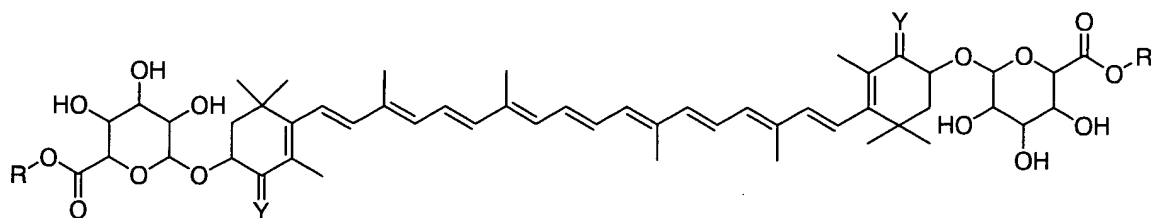


15    100.    The compound of claim 97, wherein Y is O, the carotenoid derivative having the structure



20    101.    The compound of claim 97, wherein the carotenoid derivative further comprises at least one chiral center.

102.    A chemical compound comprising a carotenoid derivative having the structure

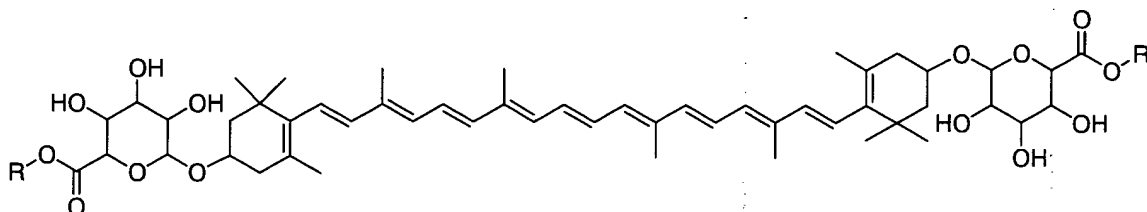


where each Y is independently O or H<sub>2</sub>;

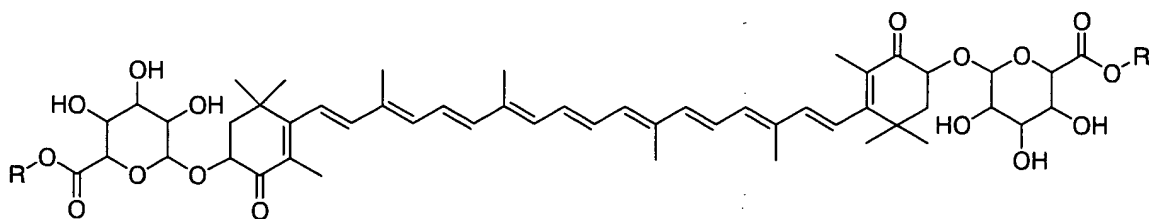
5 where each R is independently H, alkyl, or aryl.

103. The compound of claim 102, wherein the carotenoid derivative is at least partially water soluble.

10 104. The compound of claim 102, wherein Y is H<sub>2</sub>, the carotenoid derivative having the structure



15 105. The compound of claim 102, wherein Y is O, the carotenoid derivative having the structure



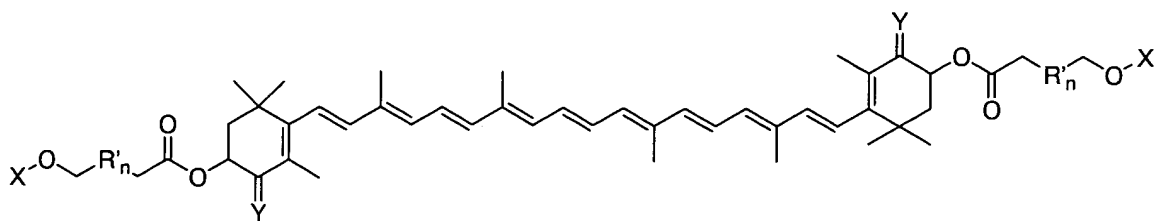
20 106. The compound of claim 102, wherein the carotenoid derivative further comprises at least one chiral center.

107. A chemical compound comprising a carotenoid derivative having the structure

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Meyertons, Hood, Kivlin,  
Kowert & Goetzel, P.C.





where each Y is independently O or H<sub>2</sub>;

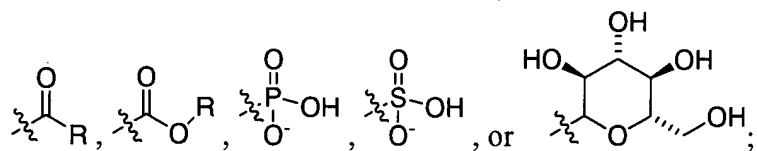
5

where R' is CH<sub>2</sub>;

where n is 1 to 9;

10

where each X is independently



where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>,  
polyethylene glycol, dextran, H, alkyl, or aryl;

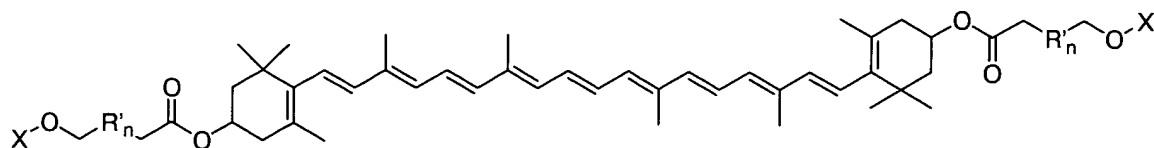
15

where each R<sup>1</sup> is independently H, alkyl, or aryl.

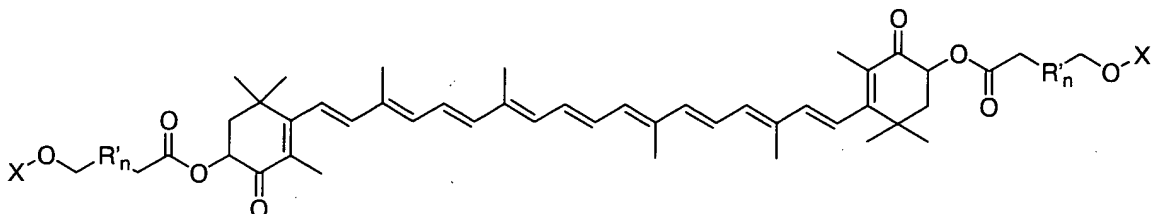
108. The compound of claim 107, wherein the carotenoid derivative is at least partially water soluble.

20

109. The compound of claim 107, wherein Y is H<sub>2</sub>, the carotenoid derivative having the structure

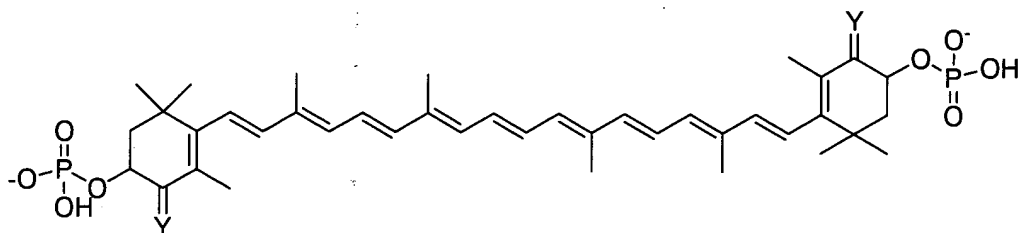


110. The compound of claim 107, wherein Y is O, the carotenoid derivative having the structure



111. The compound of claim 107, wherein the carotenoid derivative further comprises at least one chiral center.

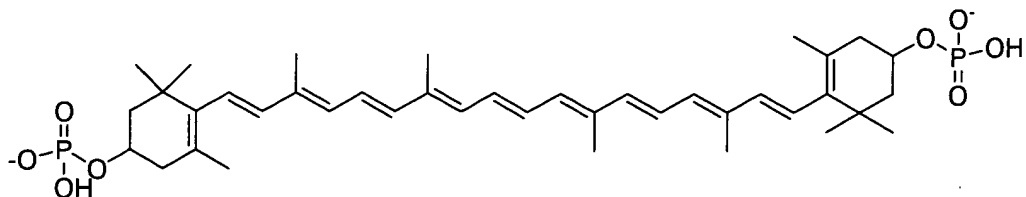
112. A chemical compound comprising a carotenoid derivative having the structure



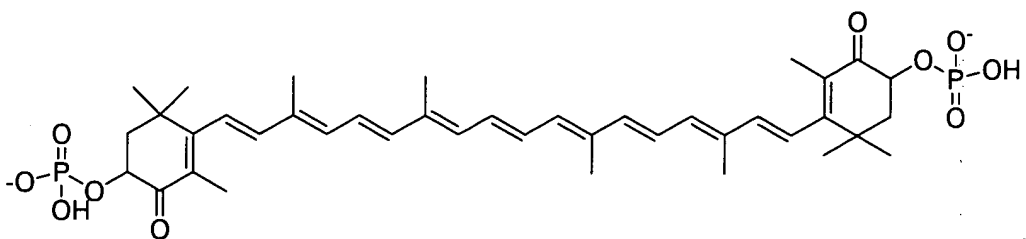
where each Y is independently O or H<sub>2</sub>.

113. The compound of claim 111, wherein the carotenoid derivative is at least partially water soluble.

114. The compound of claim 111, wherein Y is H<sub>2</sub>, the carotenoid derivative having the structure



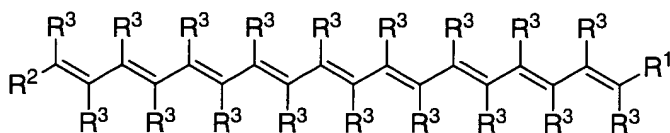
115. The compound of claim 111, wherein Y is O, the carotenoid derivative having the structure



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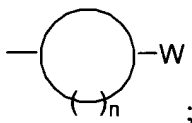
116. The compound of claim 111, wherein the carotenoid derivative further comprises at least one chiral center.

- 10 117. A pharmaceutical composition comprising a carotenoid derivative having the structure



15 where each  $R^3$  is independently hydrogen or methyl;

where  $R^1$  and  $R^2$  are independently an acyclic alkene comprising at least one substituent or a cyclic ring comprising at least one substituent, wherein the cyclic ring having general structure:

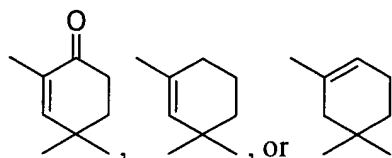


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where n is 4 to 10 carbon atoms; and

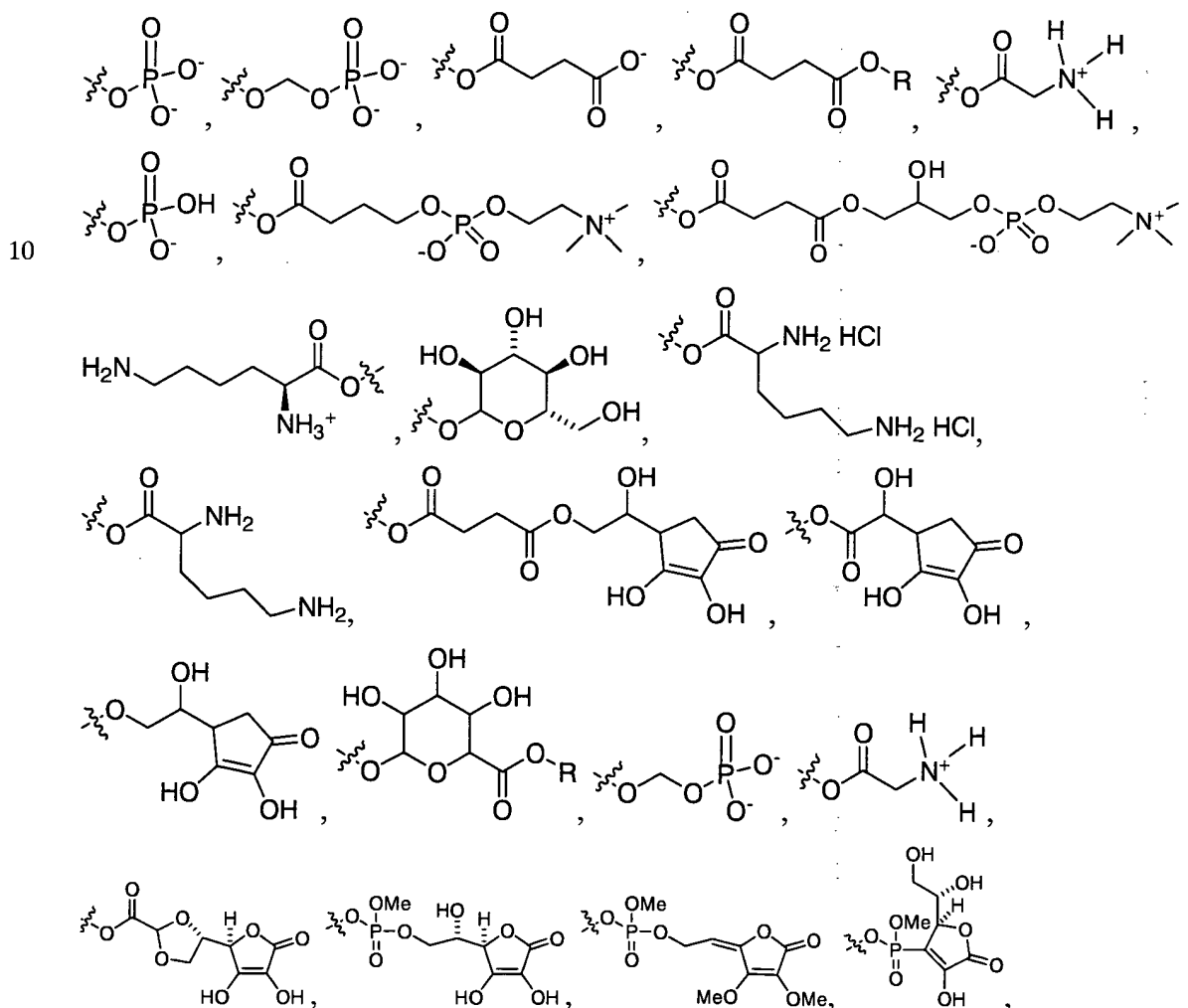
where W is the substituent.

- 5     118.    The composition of claim 117, wherein each of the substituents –W independently  
         comprises –XR, wherein each X independently comprises O, N, or S.
119.    The composition of claim 117, wherein each of the substituents –W  
                 independently comprises amino acids, esters, carbamates, amides, carbonates,  
10       alcohol, phosphates, or sulfonates.
120.    The composition of claim 117, wherein the carotenoid derivative is at least  
                 partially water soluble.
- 15     121.    The composition of claim 117, wherein the substituent is at least partially  
                 hydrophilic.
122.    The composition of claim 117, wherein the cyclic ring further comprises at least  
                 one chiral center.
- 20     123.    The composition of claim 117, further comprising human serum albumin.
124.    The composition of claim 123, wherein human serum albumin is in molar excess  
                 of the carotenoid derivative.
- 25     125.    The composition of claim 117, wherein the cyclic ring further comprises at least  
                 one degree of unsaturation.
126.    The composition of claim 117, wherein each cyclic ring is independently  
30



127. The composition of claim 117, wherein the substituent is a carboxylic acid, an ester, an alkanol, an amine, a phosphate, a succinate, a glycinate, an ether, a glucoside, a sugar, or a carboxylate salt.

128. The composition of claim 117, wherein each substituent is independently

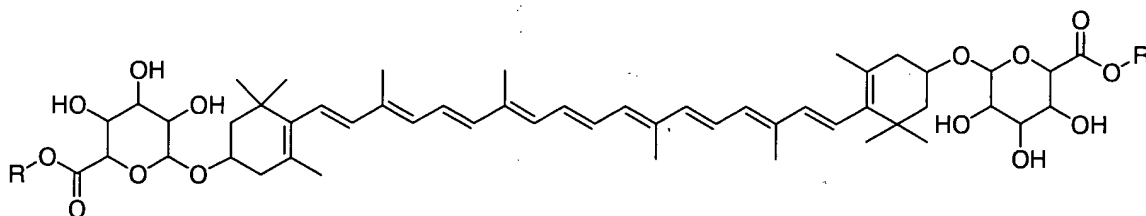




lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or canthaxanthin.

131. The composition of claim 117, further comprising a second carotenoid derivative  
5 in combination with the carotenoid derivative.

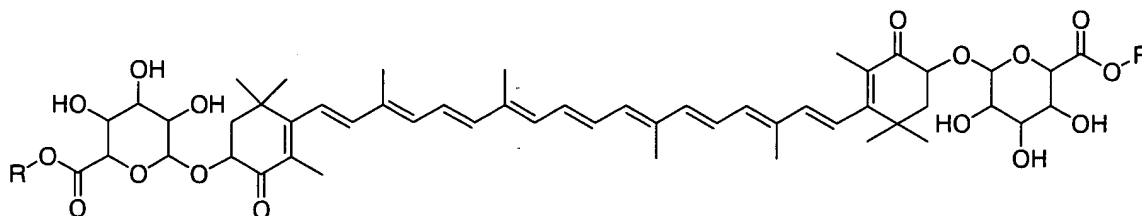
132. The composition of claim 117, wherein the carotenoid derivative having the structure



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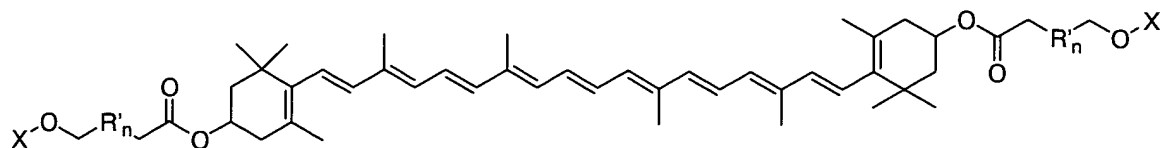
where each R is independently -alkyl-NR<sub>3</sub><sup>+</sup>, -aromatic-NR<sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

133. The composition of claim 117, wherein the carotenoid derivative having the structure



where each R is independently -alkyl-NR<sub>3</sub><sup>+</sup>, -aromatic-NR<sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
20 H, alkyl, or aryl.

134. The composition of claim 117, wherein the carotenoid derivative having the structure



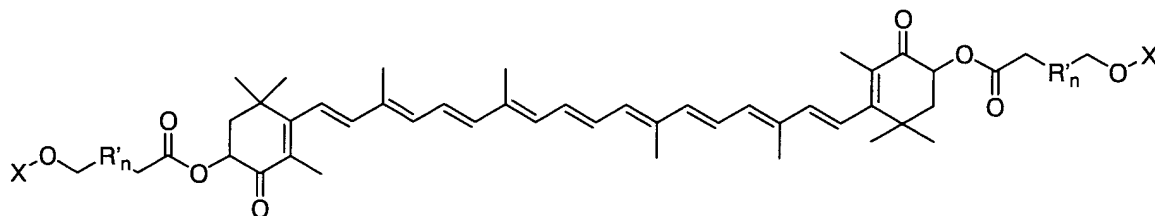
where each X is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
 5 H, alkyl, or aryl;

where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

10

135. The composition of claim 117, wherein the carotenoid derivative having the structure



15 where each X is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

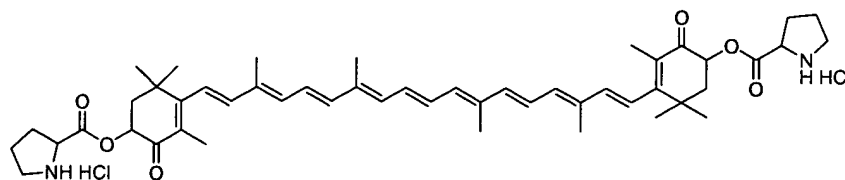
where each R' is independently -alkyl-O, alkyl, or aryl; and

20

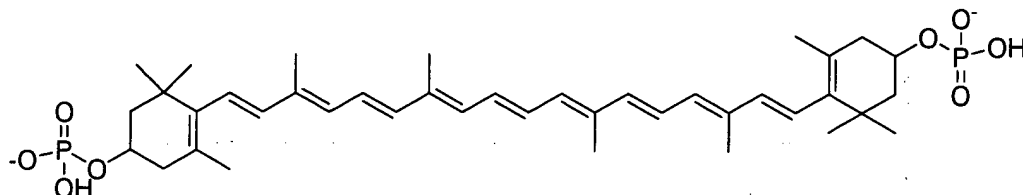
where n is between about 0 and 12.

136. The composition of claim 117, wherein the carotenoid derivative having the structure



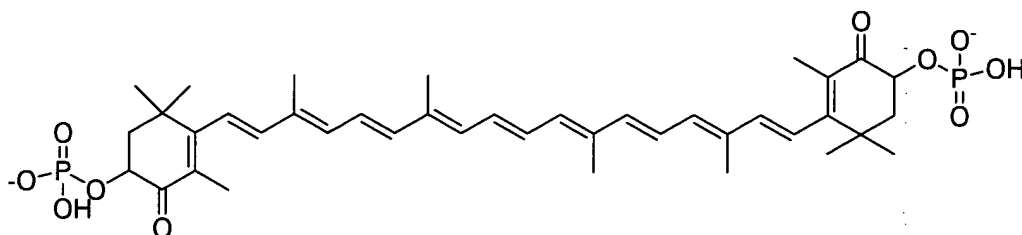


137. The composition of claim 117, wherein the carotenoid derivative having the structure



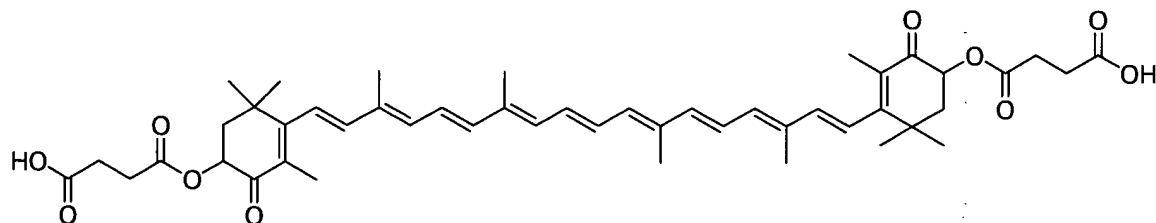
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138. The composition of claim 117, wherein the carotenoid derivative having the structure

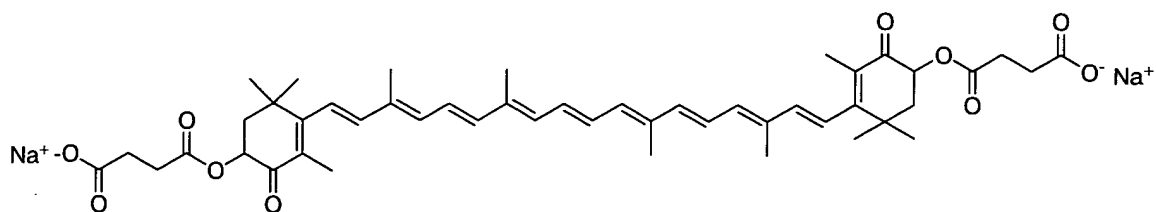


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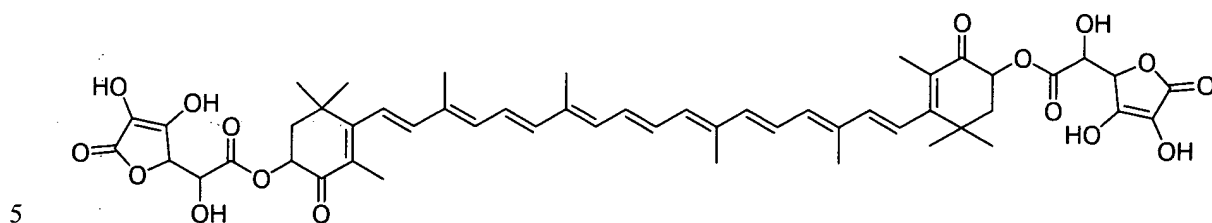
139. The composition of claim 117, wherein the carotenoid derivative having the structure



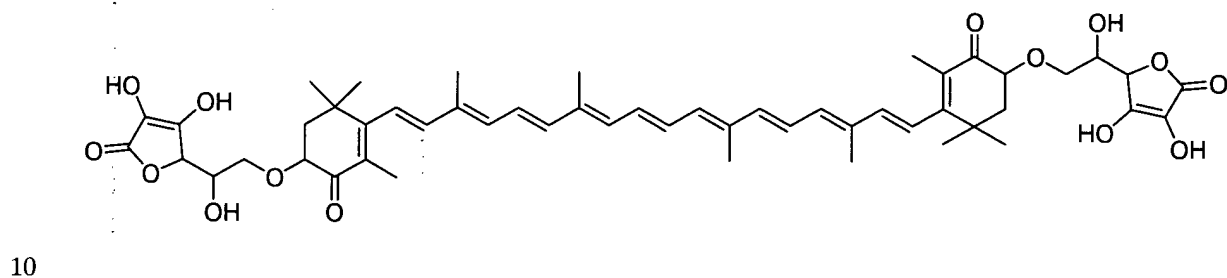
- 15 140. The composition of claim 117, wherein the carotenoid derivative having the structure



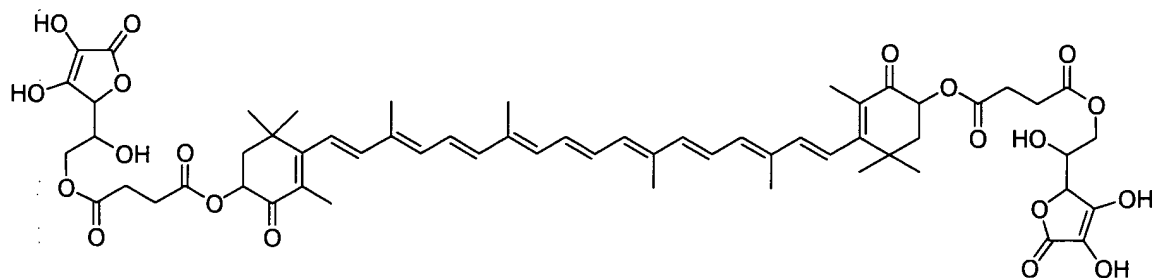
141. The composition of claim 117, wherein the carotenoid derivative having the structure



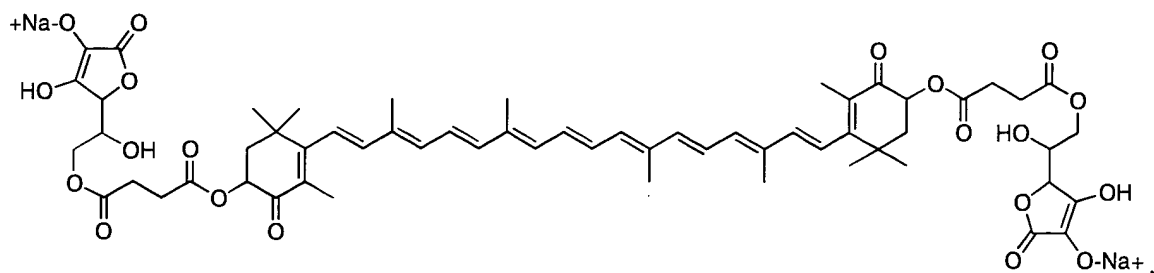
142. The composition of claim 117, wherein the carotenoid derivative having the structure



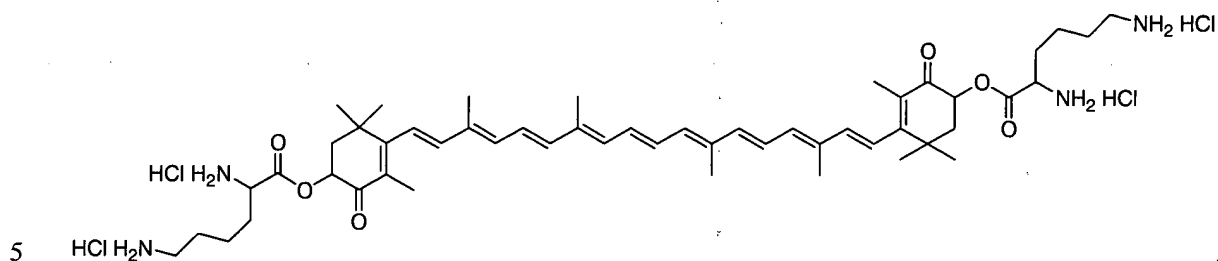
143. The composition of claim 117, wherein the carotenoid derivative having the structure



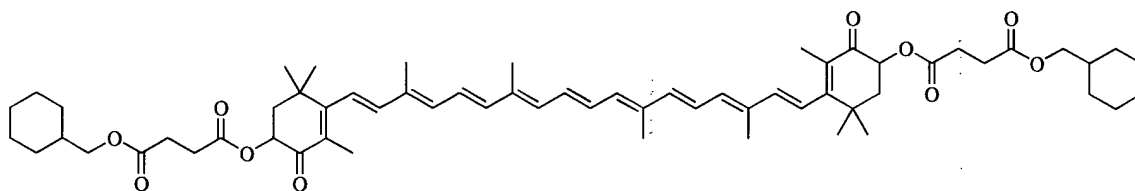
- 15 144. The composition of claim 117, wherein the carotenoid derivative having the structure



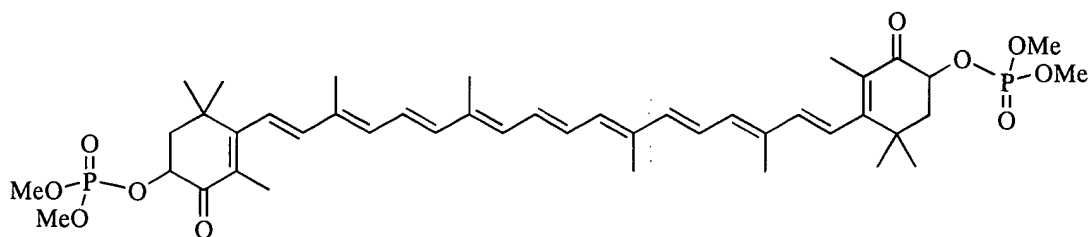
145. The composition of claim 117, wherein the carotenoid derivative having the structure



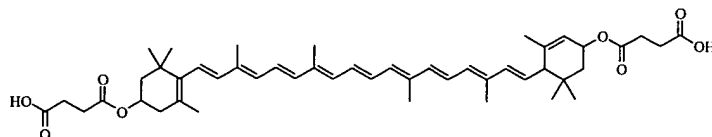
146. The composition of claim 117, wherein the carotenoid derivative having the structure



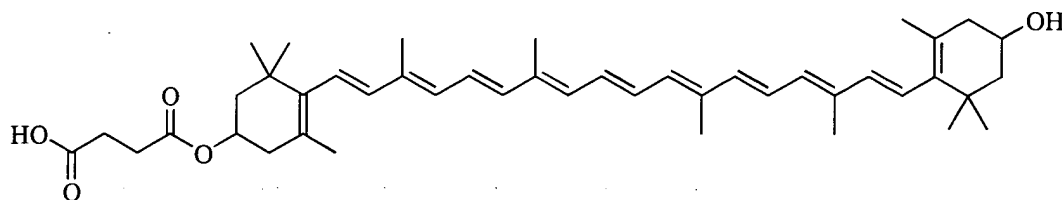
147. The composition of claim 117, wherein the carotenoid derivative having the structure



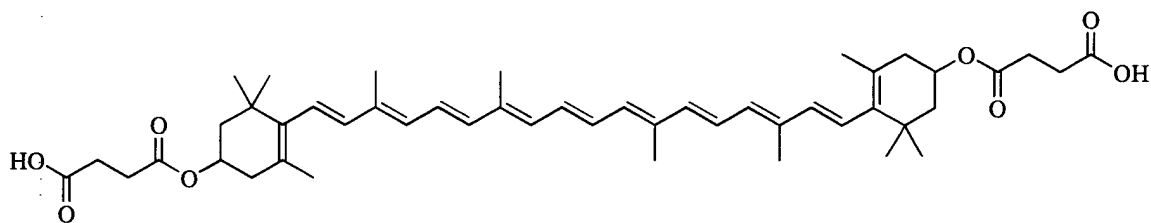
148. The composition of claim 117, wherein the carotenoid derivative having the structure



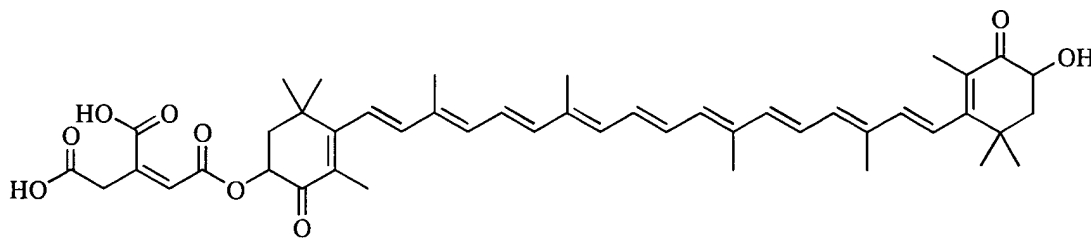
149. The composition of claim 117, wherein the carotenoid derivative having the structure



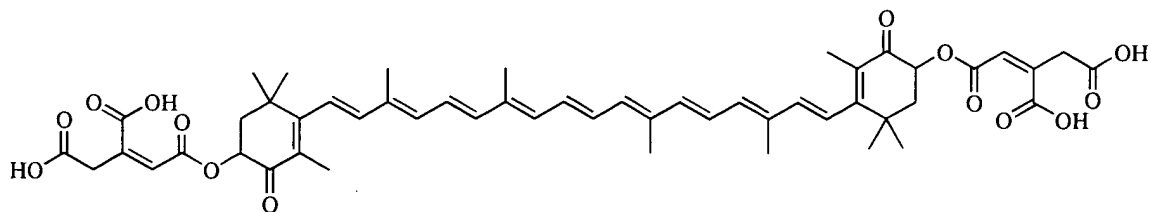
150. The composition of claim 117, wherein the carotenoid derivative having the structure



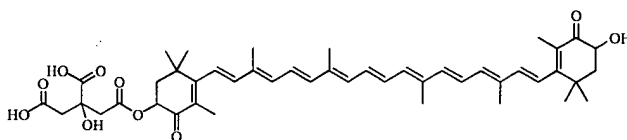
151. The composition of claim 117, wherein the carotenoid derivative having the structure



152. The composition of claim 117, wherein the carotenoid derivative having the structure

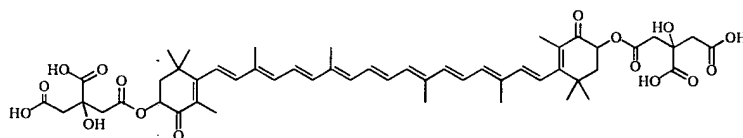


153. The composition of claim 117, wherein the carotenoid derivative having the structure



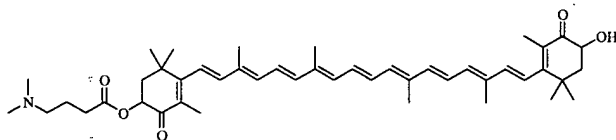
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154. The composition of claim 117, wherein the carotenoid derivative having the structure

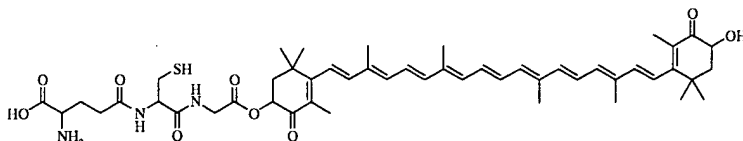


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155. The composition of claim 117, wherein the carotenoid derivative having the structure

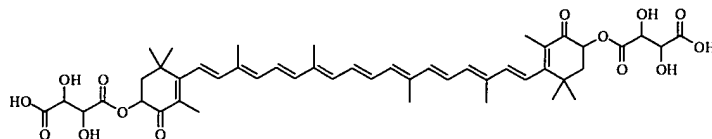


156. The composition of claim 117, wherein the carotenoid derivative having the structure

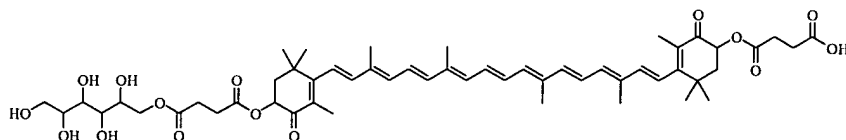


157. The composition of claim 117, wherein the carotenoid derivative having the structure

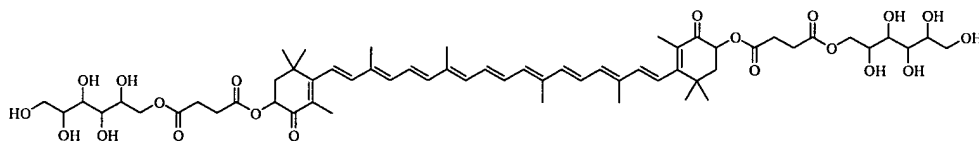
20



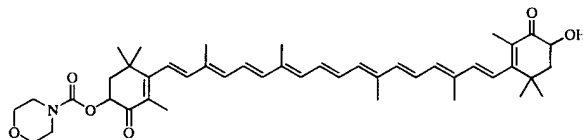
158. The composition of claim 117, wherein the carotenoid derivative having the structure



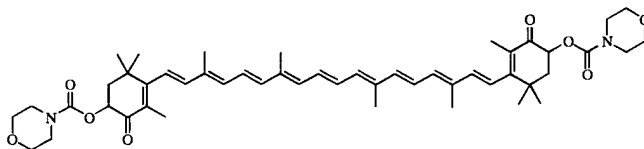
159. The composition of claim 117, wherein the carotenoid derivative having the structure



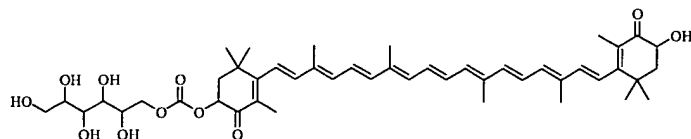
160. The composition of claim 117, wherein the carotenoid derivative having the structure



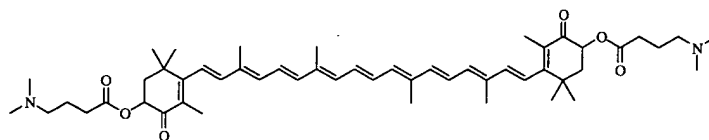
161. The composition of claim 117, wherein the carotenoid derivative having the structure



162. The composition of claim 117, wherein the carotenoid derivative having the structure

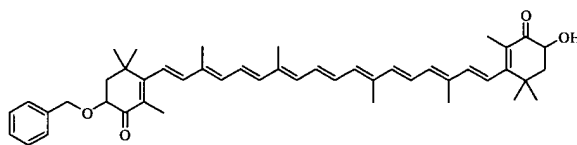


163. The composition of claim 117, wherein the carotenoid derivative having the structure



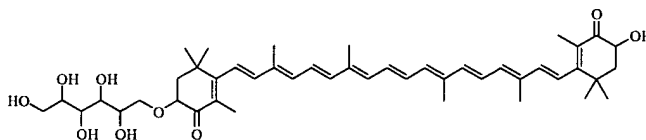
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164. The composition of claim 117, wherein the carotenoid derivative having the structure



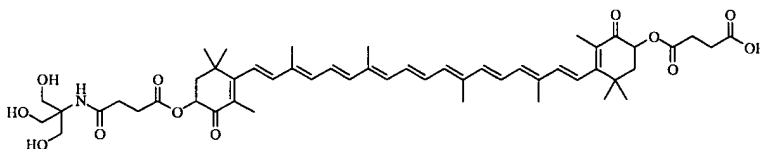
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165. The composition of claim 117, wherein the carotenoid derivative having the structure



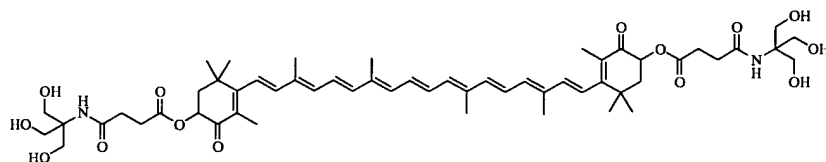
15

166. The composition of claim 117, wherein the carotenoid derivative having the structure

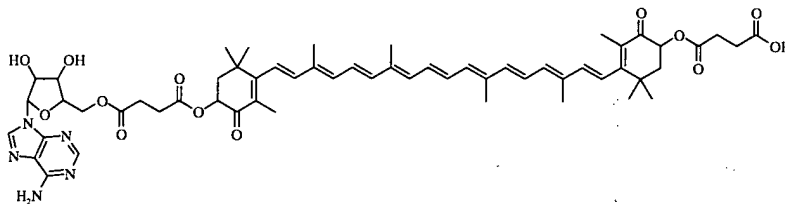


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167. The composition of claim 117, wherein the carotenoid derivative having the structure

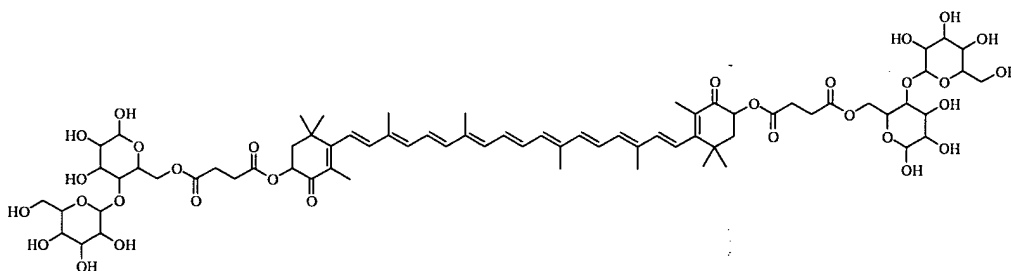


168. The composition of claim 117, wherein the carotenoid derivative having the structure



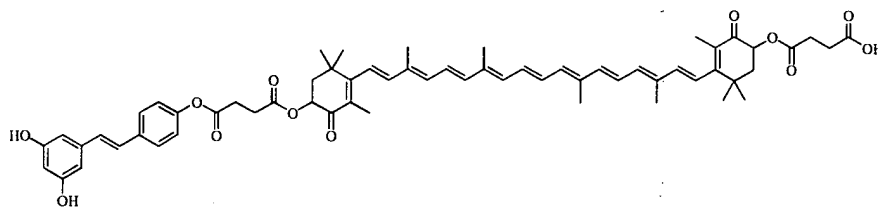
5

169. The composition of claim 117, wherein the carotenoid derivative having the structure



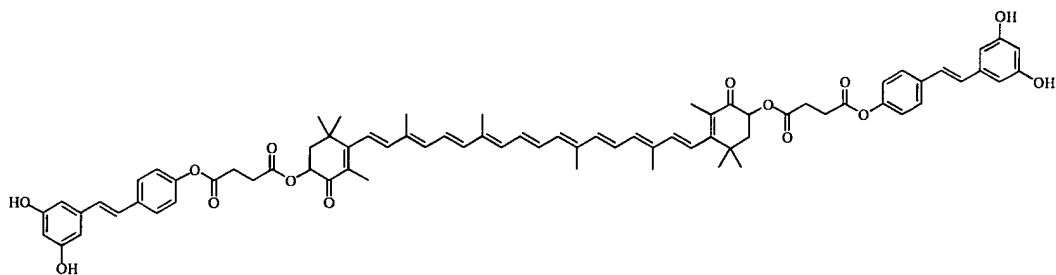
10

170. The composition of claim 117, wherein the carotenoid derivative having the structure



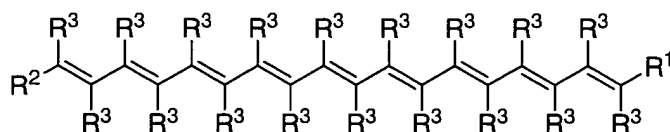
- 15 171. The composition of claim 117, wherein the carotenoid derivative having the structure





172. A pharmaceutical composition, comprising:

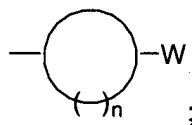
5 a carotenoid derivative having the structure



where each  $R^3$  is independently hydrogen or methyl;

where  $R^1$  and  $R^2$  are independently an acyclic alkene comprising at least one substituent or a cyclic ring comprising at least one substituent,

wherein the cyclic ring having general structure:



where  $n$  is 4 to 10 carbon atoms; and

where  $W$  is the substituent; and

human serum albumin, wherein human serum albumin is in a molar excess to that of the carotenoid derivative.

173. The composition of claim 172, wherein each of the substituents  $-W$  independently comprises  $-XR$ , wherein each  $X$  independently comprises O, N, or S.

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Meyertons, Hood, Kivlin,  
Kowert & Goetzel, P.C.

174. The composition of claim 172, wherein each of the substituents -W independently comprises amino acids, esters, carbamates, amides, carbonates, alcohol, phosphates, or sulfonates.

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175. The composition of claim 172, wherein the carotenoid derivative is at least partially water soluble.

10

176. The composition of claim 172, wherein the substituent is at least partially hydrophilic.

177. The composition of claim 172, wherein the cyclic ring further comprises at least one chiral center.

15

178. The composition of claim 172, further comprising human serum albumin.

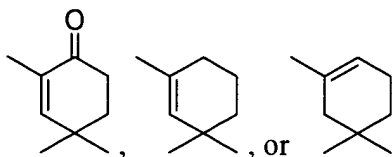
179. The composition of claim 172, wherein human serum albumin is in molar excess of the carotenoid derivative.

20

180. The composition of claim 172, wherein the cyclic ring further comprises at least one degree of unsaturation.

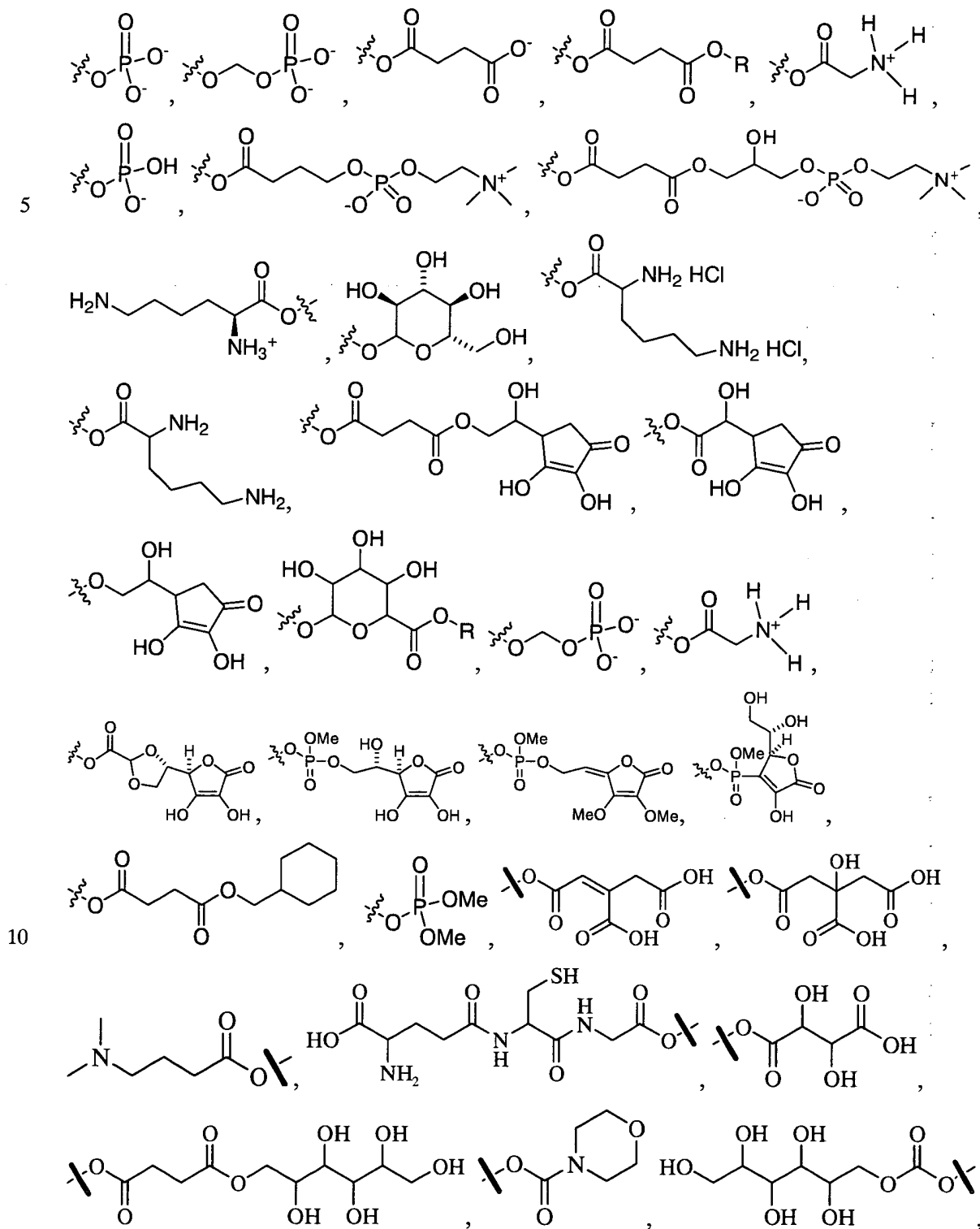
181. The composition of claim 172, wherein each cyclic ring is independently

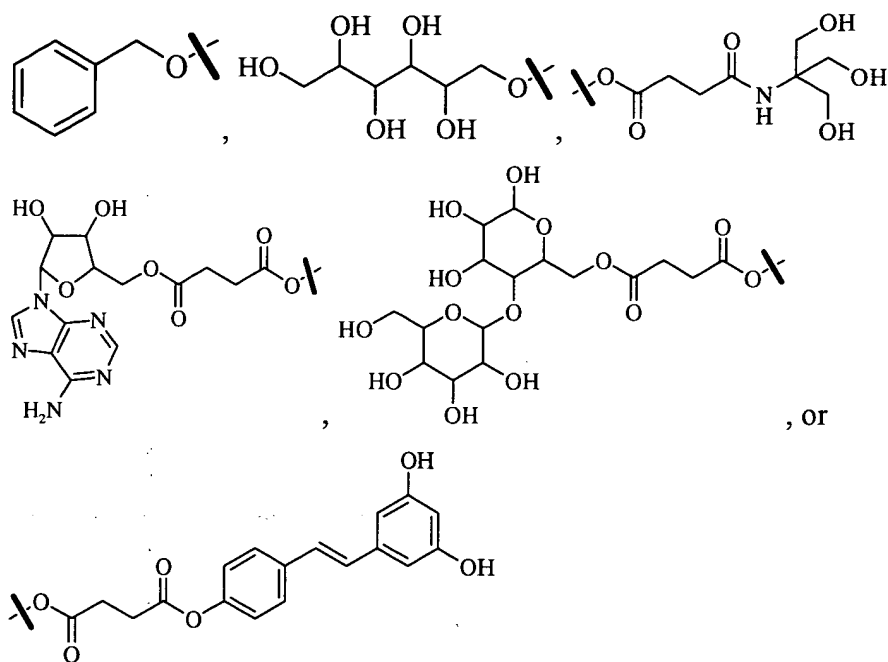
25



182. The composition of claim 172, wherein the substituent is a carboxylic acid, an ester, an alkanol, an amine, a phosphate, a succinate, a glycinate, an ether, a glucoside, a sugar, or a carboxylate salt.

183. The composition of claim 172, wherein each substituent is independently





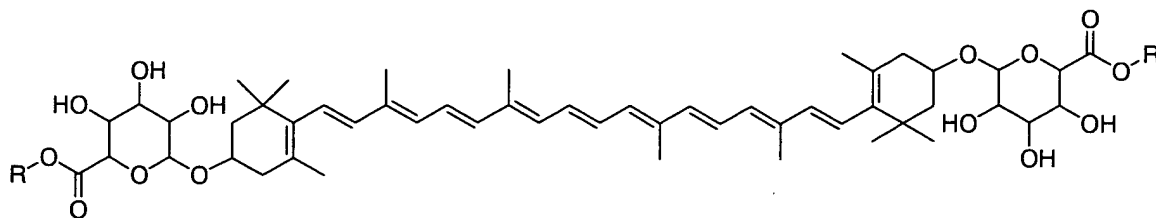
5 where each R is independently -alkyl-NR<sub>3</sub><sup>+</sup>, -aromatic-NR<sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

10 184. The composition of claim 172, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid.

15 185. The composition of claim 172, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid, and wherein the naturally occurring carotenoid is lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or canthaxanthin.

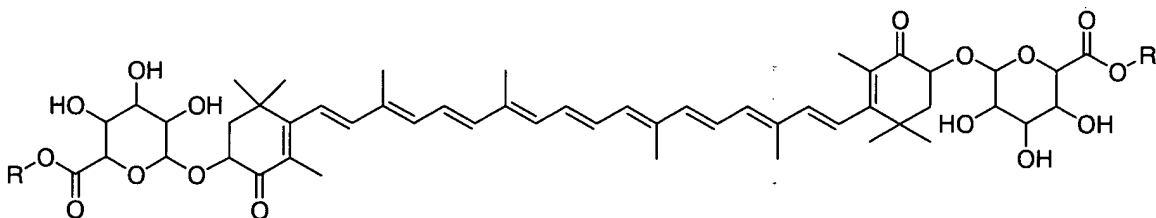
186. The composition of claim 172, further comprising a second carotenoid derivative in combination with the carotenoid derivative.

20 187. The composition of claim 172, wherein the carotenoid derivative having the structure



where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
 5 H, alkyl, or aryl.

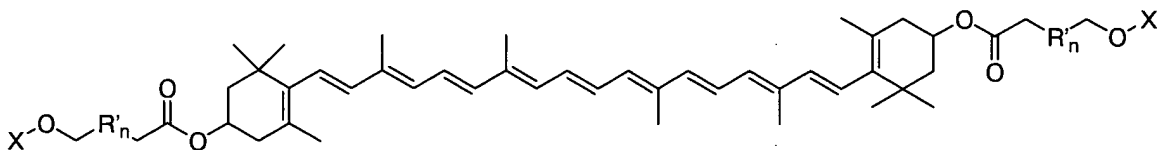
188. The composition of claim 172, wherein the carotenoid derivative having the structure



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where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
 H, alkyl, or aryl.

15 189. The composition of claim 172, wherein the carotenoid derivative having the structure

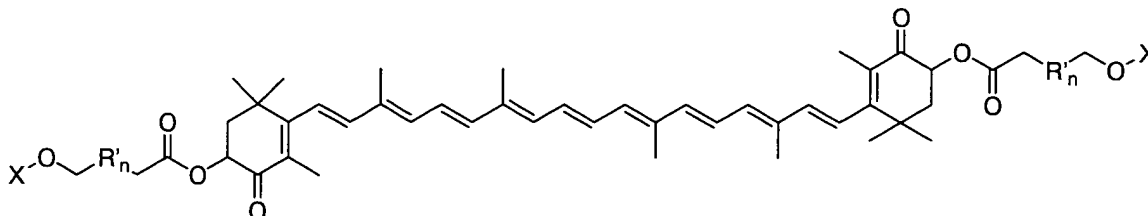


where each X is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
 20 H, alkyl, or aryl;

where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

190. The composition of claim 172, wherein the carotenoid derivative having the structure

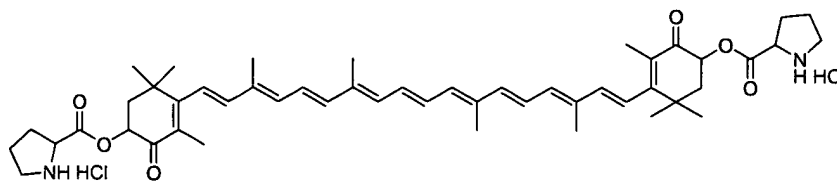


- where each X is independently  $-alkyl-NR_3^+$ ,  $-aromatic-NR_3^+$ ,  $-alkyl-CO_2^-$ ,  $-aromatic-CO_2^-$ ,  $-amino\ acid-NH_3^+$ ,  $-phosphorylated\ amino\ acid-NH_3^+$ , polyethylene glycol, dextran, H, alkyl, or aryl;

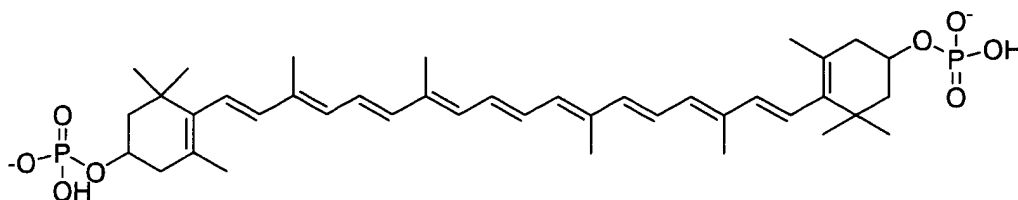
where each R' is independently  $-alkyl-O$ , alkyl, or aryl; and

where n is between about 0 and 12.

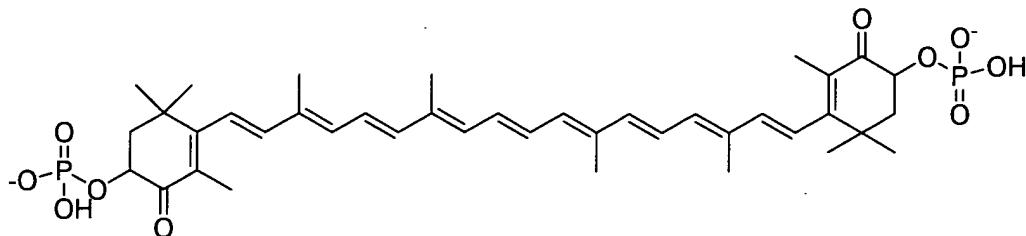
191. The composition of claim 172, wherein the carotenoid derivative having the structure



192. The composition of claim 172, wherein the carotenoid derivative having the structure

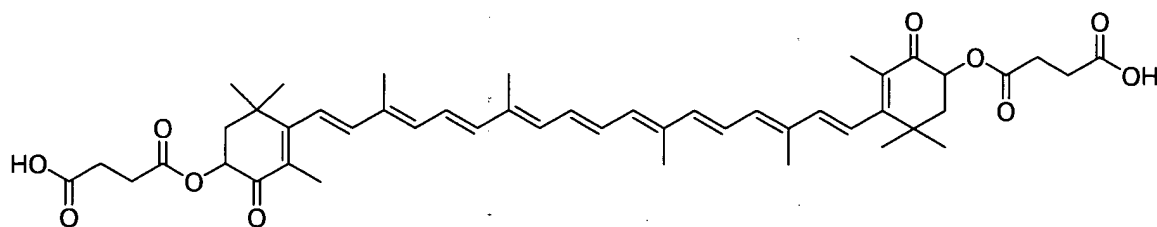


193. The composition of claim 172, wherein the carotenoid derivative having the structure

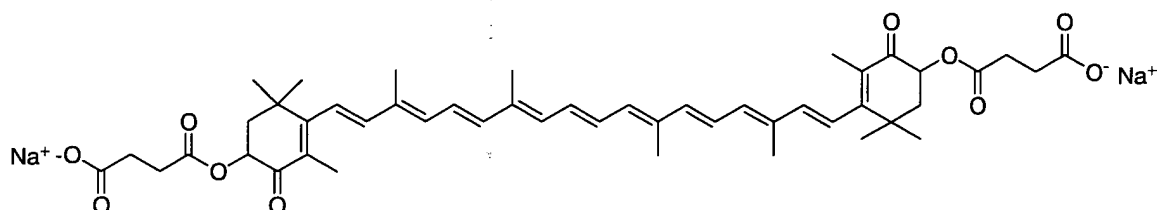


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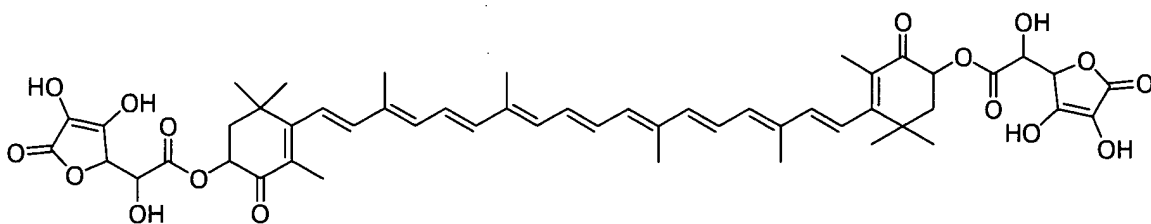
194. The composition of claim 172, wherein the carotenoid derivative having the structure



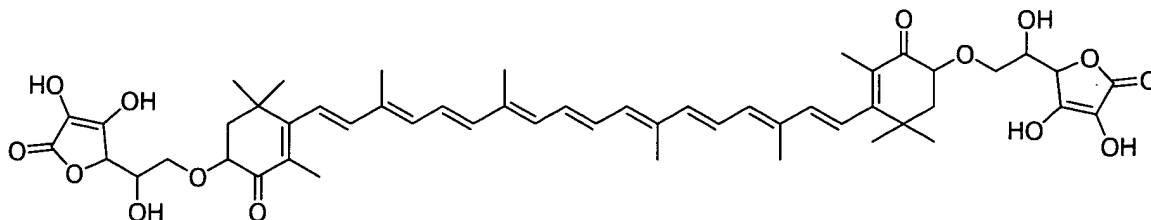
- 10 195. The composition of claim 172, wherein the carotenoid derivative having the structure



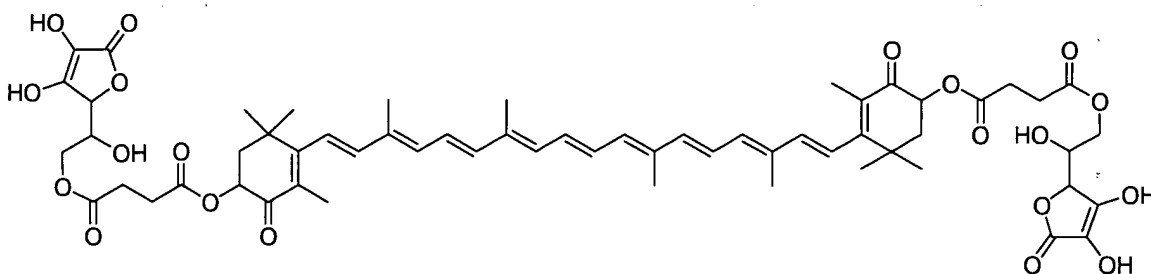
- 15 196. The composition of claim 172, wherein the carotenoid derivative having the structure



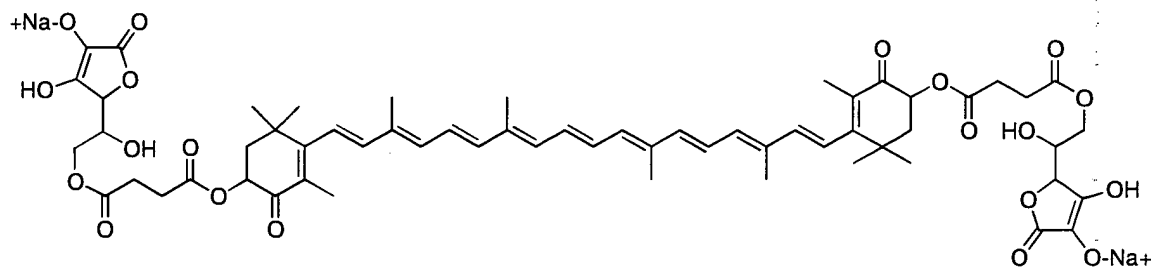
197. The composition of claim 172, wherein the carotenoid derivative having the structure



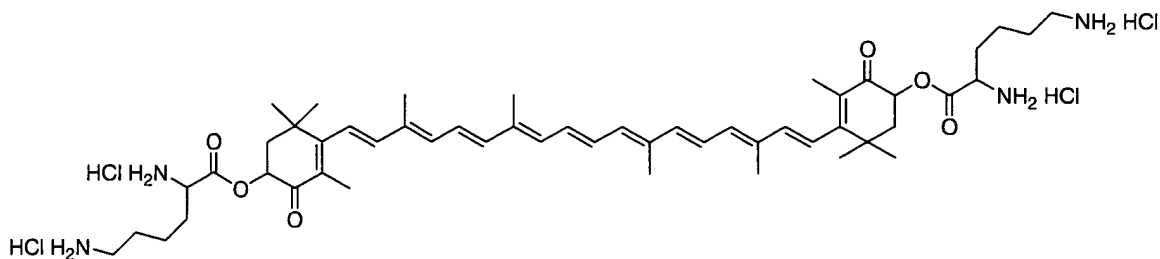
198. The composition of claim 172, wherein the carotenoid derivative having the structure



199. The composition of claim 172, wherein the carotenoid derivative having the structure

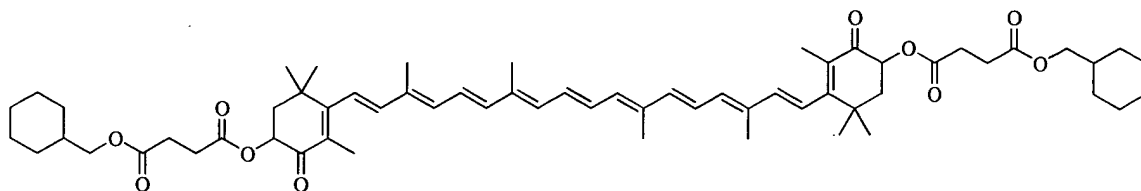


200. The composition of claim 172, wherein the carotenoid derivative having the structure



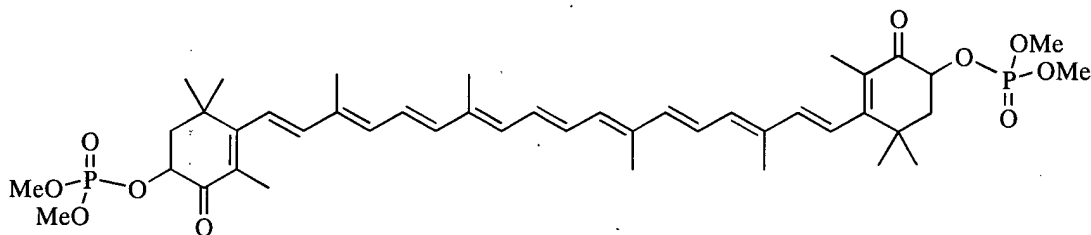


201. The composition of claim 172, wherein the carotenoid derivative having the structure

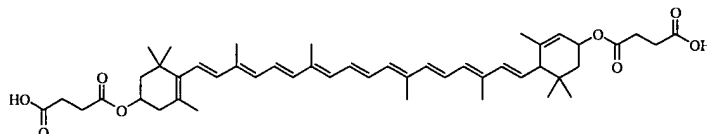


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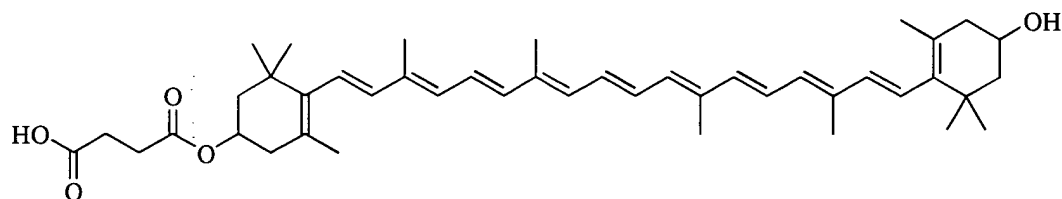
202. The composition of claim 172, wherein the carotenoid derivative having the structure



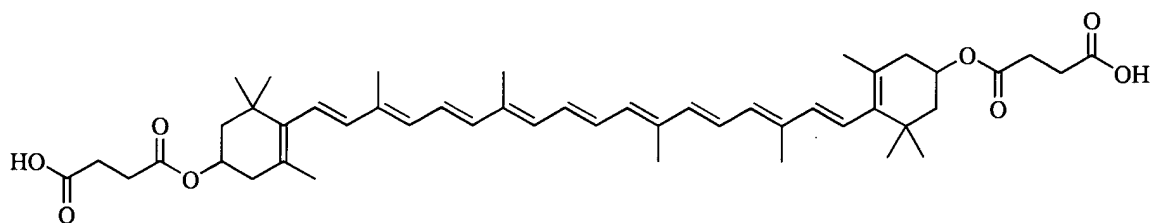
10 203. The composition of claim 172, wherein the carotenoid derivative having the structure



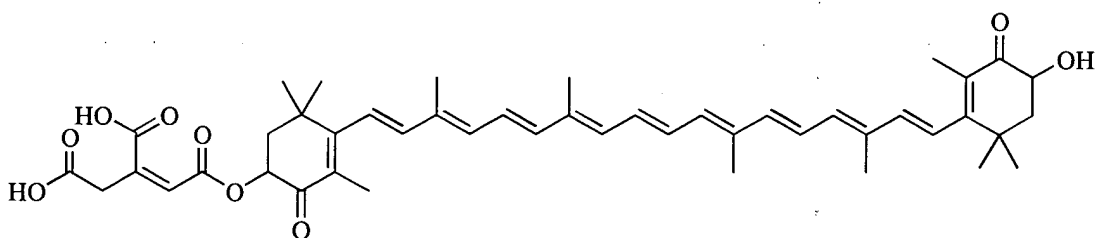
15 204. The composition of claim 172, wherein the carotenoid derivative having the structure



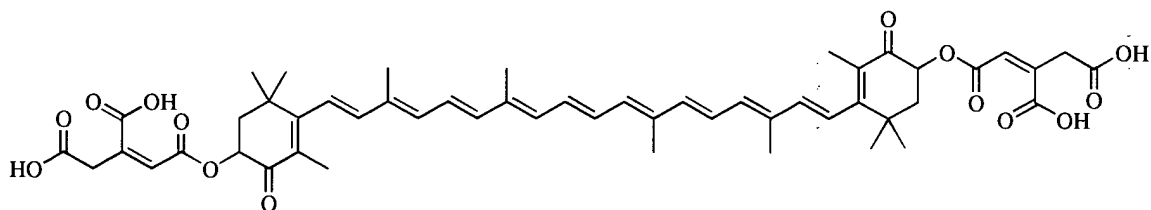
205. The composition of claim 172, wherein the carotenoid derivative having the structure



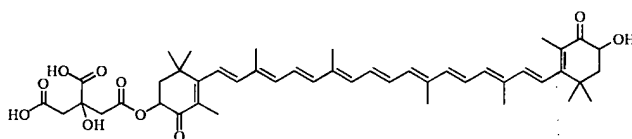
206. The composition of claim 172, wherein the carotenoid derivative having the structure



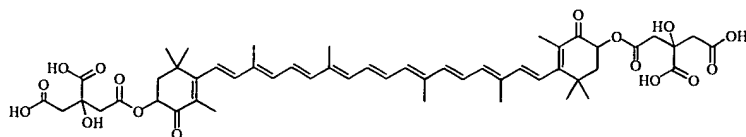
207. The composition of claim 172, wherein the carotenoid derivative having the structure



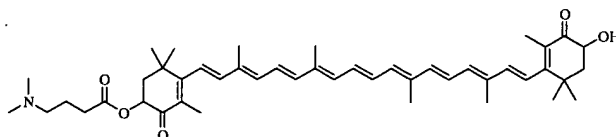
208. The composition of claim 172, wherein the carotenoid derivative having the structure



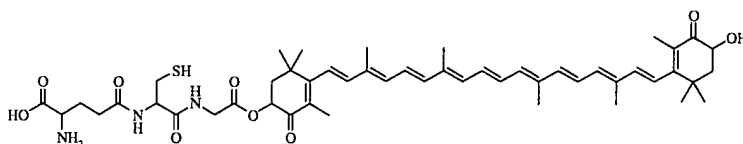
209. The composition of claim 172, wherein the carotenoid derivative having the structure



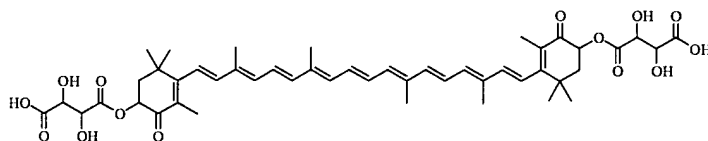
210. The composition of claim 172, wherein the carotenoid derivative having the structure



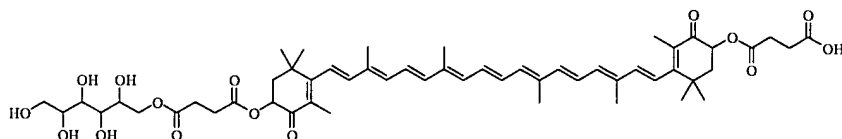
211. The composition of claim 172, wherein the carotenoid derivative having the structure



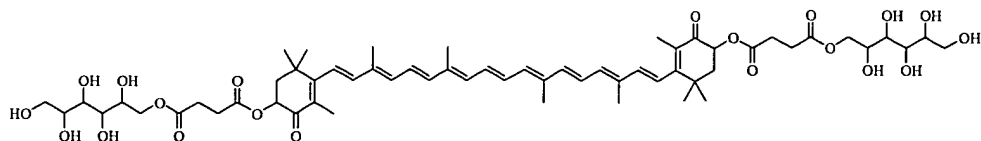
212. The composition of claim 172, wherein the carotenoid derivative having the structure



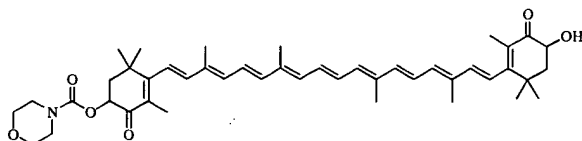
213. The composition of claim 172, wherein the carotenoid derivative having the structure



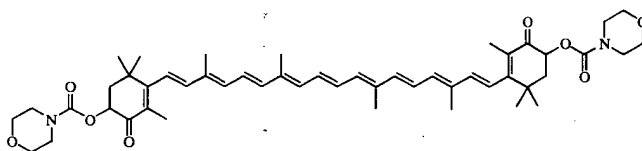
214. The composition of claim 172, wherein the carotenoid derivative having the structure



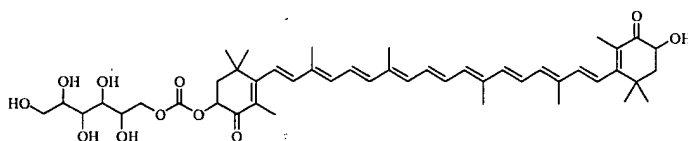
215. The composition of claim 172, wherein the carotenoid derivative having the structure



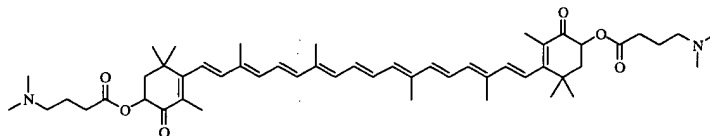
216. The composition of claim 172, wherein the carotenoid derivative having the structure



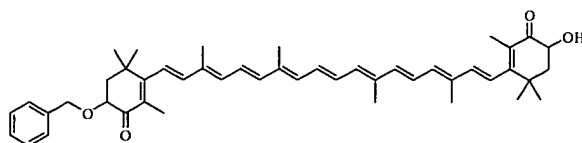
217. The composition of claim 172, wherein the carotenoid derivative having the structure



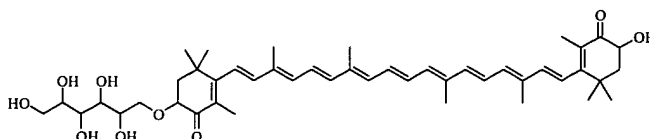
218. The composition of claim 172, wherein the carotenoid derivative having the structure



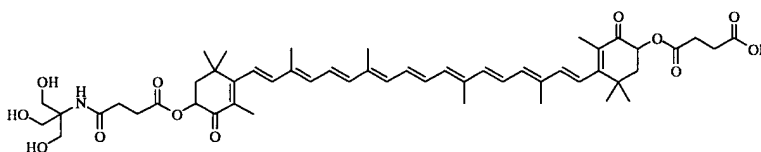
219. The composition of claim 172, wherein the carotenoid derivative having the structure



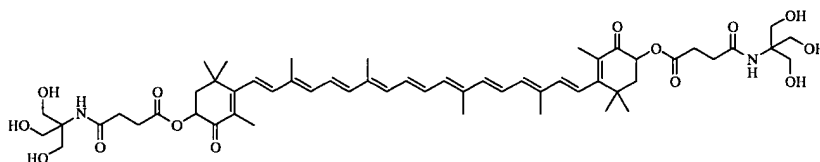
220. The composition of claim 172, wherein the carotenoid derivative having the structure



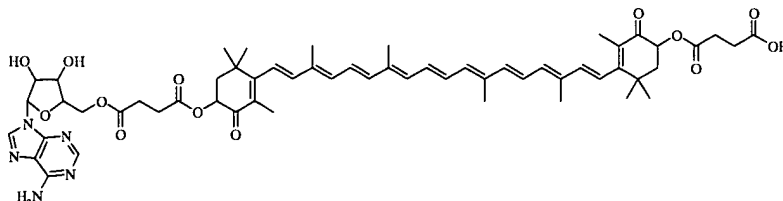
221. The composition of claim 172, wherein the carotenoid derivative having the structure



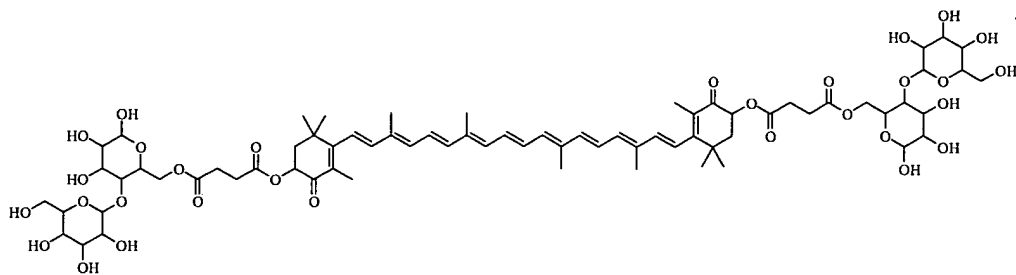
222. The composition of claim 172, wherein the carotenoid derivative having the structure



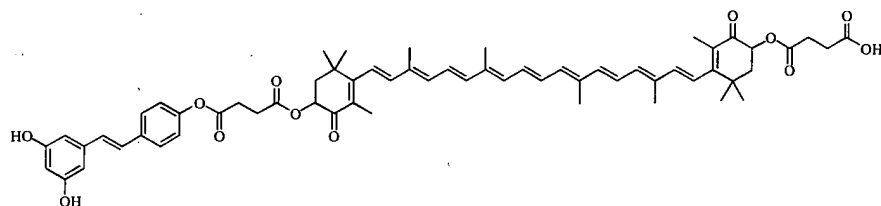
223. The composition of claim 172, wherein the carotenoid derivative having the structure



224. The composition of claim 172, wherein the carotenoid derivative having the structure

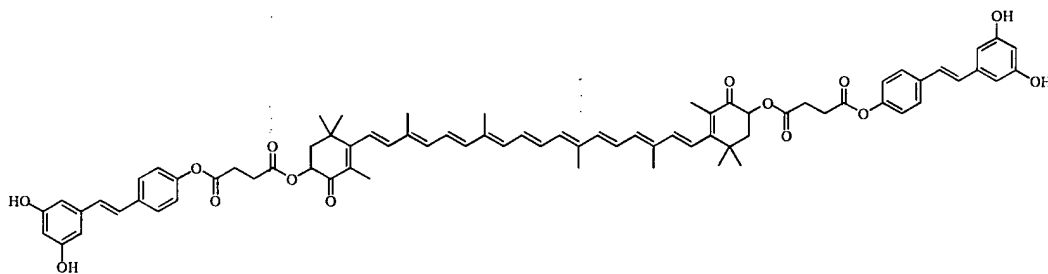


225. The composition of claim 172, wherein the carotenoid derivative having the structure



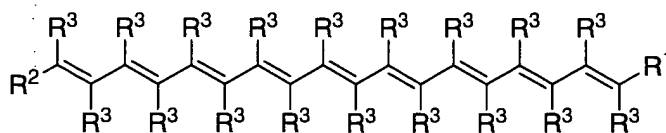
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226. The composition of claim 172, wherein the carotenoid derivative having the structure



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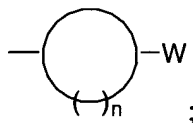
227. A method of synthesizing a chemical compound comprising a carotenoid derivative having the structure



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where each R<sup>3</sup> is independently hydrogen or methyl;

where  $R^1$  and  $R^2$  are independently an acyclic alkene comprising at least one substituent or a cyclic ring comprising at least one substituent, wherein the cyclic ring having general structure:

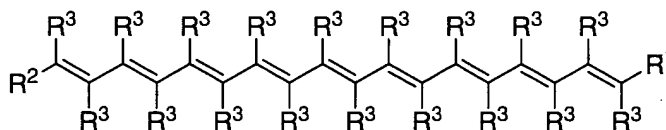


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where  $n$  is 4 to 10 carbon atoms; and

where  $W$  is the substituent;

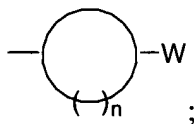
10 reacting a carotenoid with a precursor of the substituent, wherein the carotenoid has the structure



15

where each  $R^3$  is independently hydrogen or methyl; and

where  $R^1$  and  $R^2$  are independently an acyclic alkene comprising at least one alcohol or a cyclic ring comprising at least one alcohol, wherein the cyclic ring having general structure:



20

where  $n$  is 4 to 10 carbon atoms; and

where  $W$  is the alcohol.

25

228. The method of claim 227, wherein each of the substituents –W independently comprises –XR, wherein each X independently comprises O, N, or S.
229. The method of claim 227, wherein each of the substituents –W independently comprises amino acids, esters, carbamates, amides, carbonates, alcohol, phosphates, or sulfonates.
230. The method of claim 227, wherein the carotenoid derivative is at least partially water soluble.
231. The method of claim 227, wherein the substituent is at least partially hydrophilic.
232. The method of claim 227, wherein the cyclic ring further comprises at least one chiral center.
233. The method of claim 227, wherein the carotenoid derivative is a single stereoisomer.
234. The method of claim 227, wherein the carotenoid derivative is a single geometric isomer.
235. The method of claim 227, wherein the carotenoid is a single stereoisomer.
236. The method of claim 227, wherein the carotenoid is a single geometric isomer.
237. The method of claim 227, wherein the substituent comprises a leaving group.
238. The method of claim 227, wherein the substituent comprises a leaving group, and wherein the chemical compound further comprises the leaving group.



239. The method of claim 227, wherein the substituent comprises a leaving group, and wherein the leaving group is Cl, Br, tosyl, brosyl, mesyl, or trifyl.

240. The method of claim 227, further comprising deprotonating the alcohol with a non-nucleophilic base.

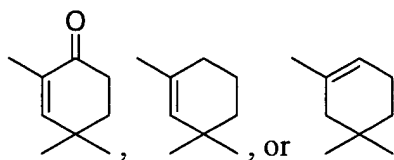
241. The method of claim 227, further comprising deprotonating the alcohol with a non-nucleophilic base, wherein the non-nucleophilic base comprise dimethylaminopyridine.

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242. The method of claim 227, wherein the cyclic ring further comprises at least one degree of unsaturation.

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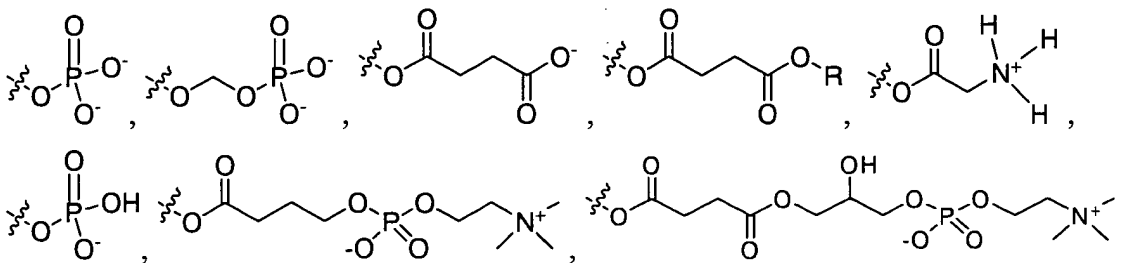
243. The method of claim 227, wherein each cyclic ring is independently



244. The method of claim 227, wherein the substituent is a carboxylic acid, an ester, an alkanol, an amine, a phosphate, a succinate, a glycinate, an ether, a glucoside, a sugar, or a carboxylate salt.

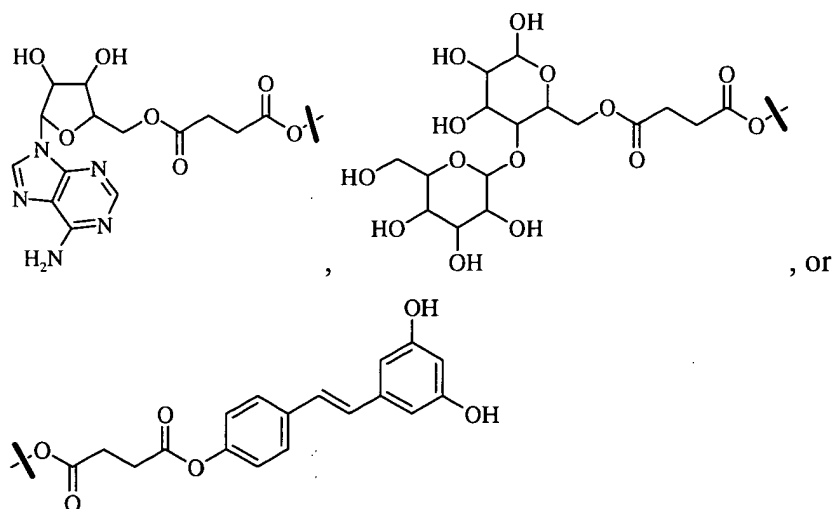
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245. The method of claim 227, wherein each substituent is independently



25





where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

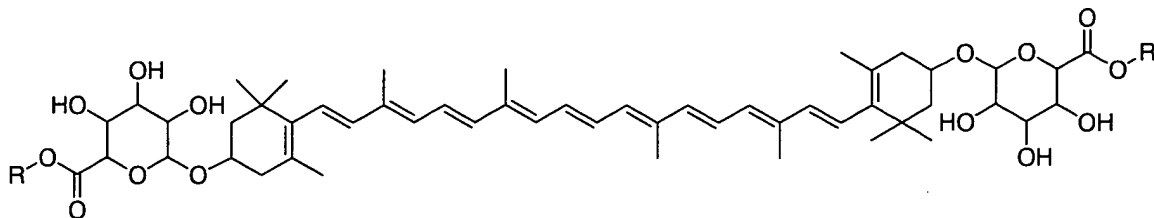
246. The method of claim 227, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid.

247. The method of claim 227, wherein the carotenoid derivative is astaxanthin.

248. The method of claim 227, wherein the precursor of the substituent is succinic acid.

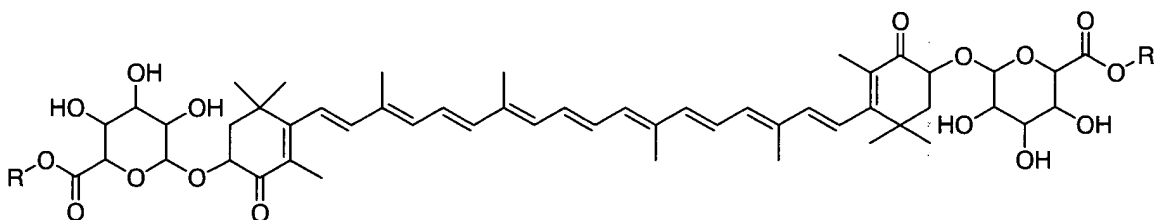
249. The method of claim 227, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid, and wherein the naturally occurring carotenoid is lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or canthaxanthin.

250. The method of claim 227, wherein the carotenoid derivative having the structure



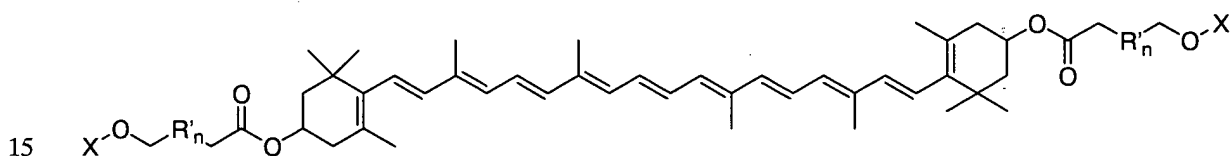
where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
 5 H, alkyl, or aryl.

251. The method of claim 227, wherein the carotenoid derivative having the structure



10 where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

252. The method of claim 227, wherein the carotenoid derivative having the structure



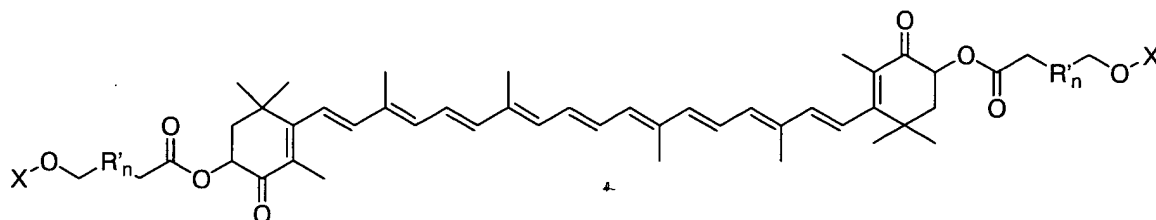
15 where each X is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

20

where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

253. The method of claim 227, wherein the carotenoid derivative having the structure



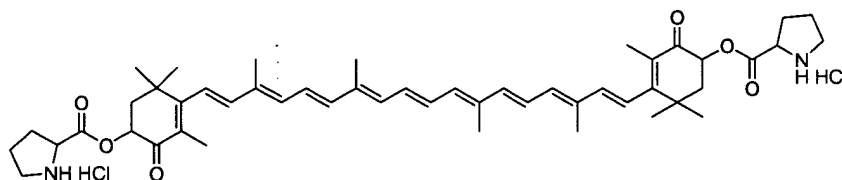
5 where each X is independently -alkyl-NR<sub>3</sub><sup>+</sup>, -aromatic-NR<sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

where each R' is independently -alkyl-O, alkyl, or aryl; and

10

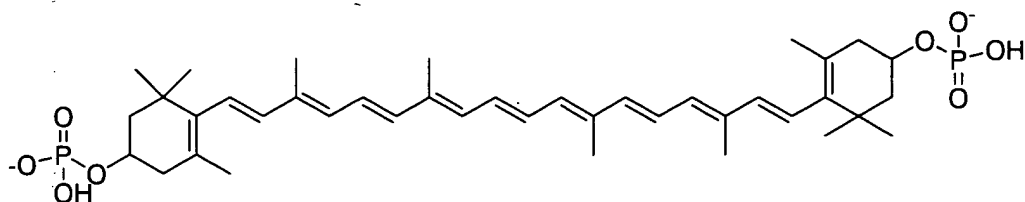
where n is between about 0 and 12.

254. The method of claim 227, wherein the carotenoid derivative having the structure

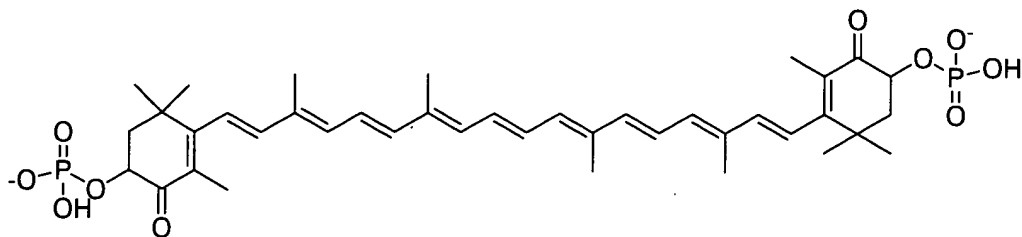


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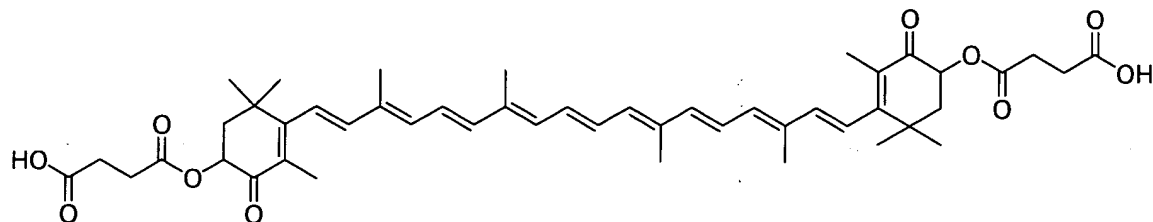
255. The method of claim 227, wherein the carotenoid derivative having the structure



256. The method of claim 227, wherein the carotenoid derivative having the structure

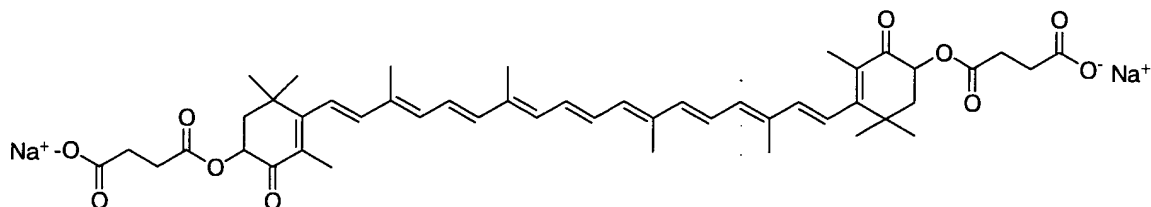


257. The method of claim 227, wherein the carotenoid derivative having the structure

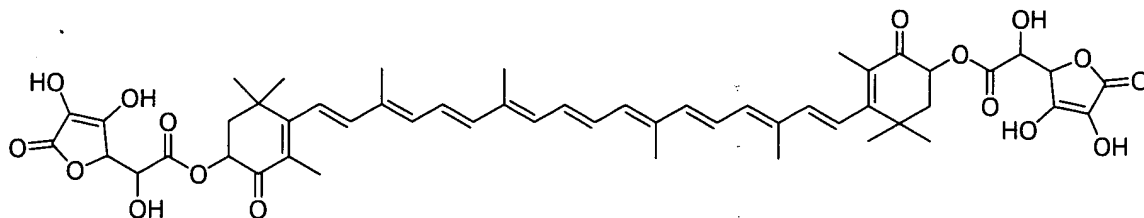


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258. The method of claim 227, wherein the carotenoid derivative having the structure

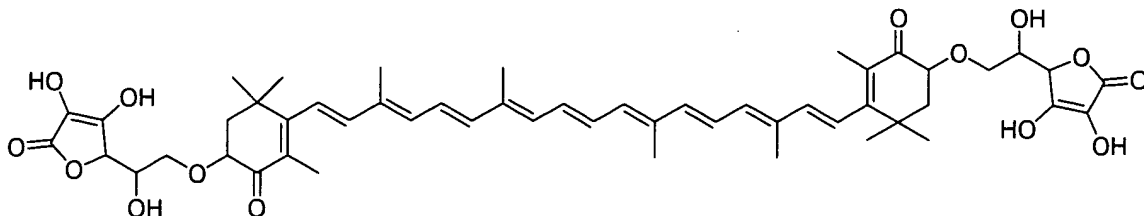


259. The method of claim 227, wherein the carotenoid derivative having the structure

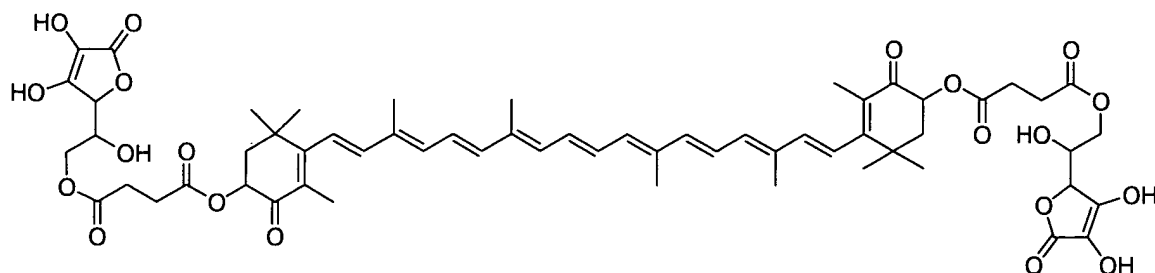


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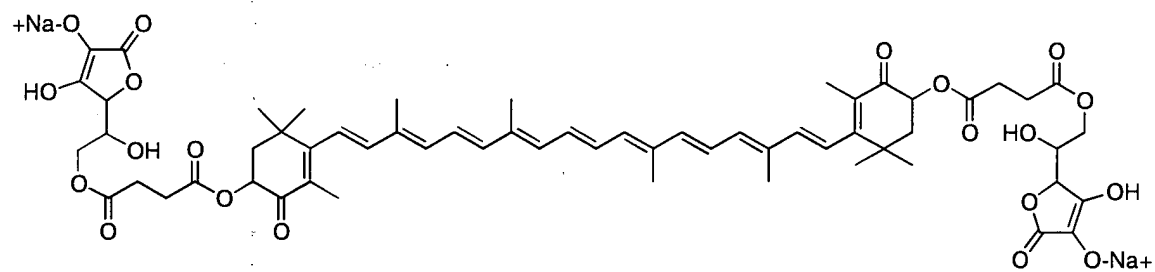
260. The method of claim 227, wherein the carotenoid derivative having the structure



261. The method of claim 227, wherein the carotenoid derivative having the structure

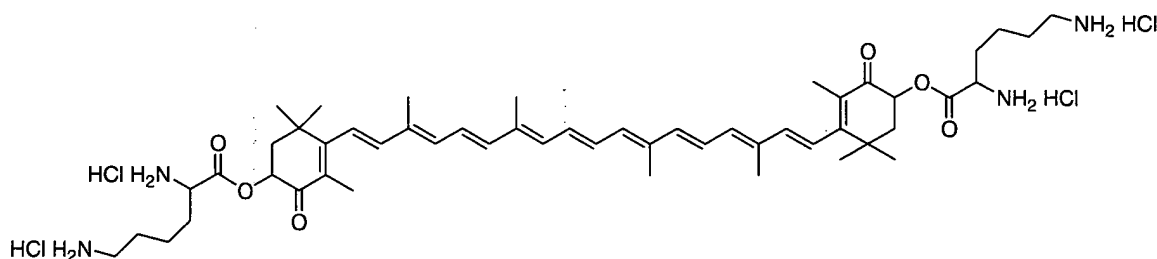


262. The method of claim 227, wherein the carotenoid derivative having the structure



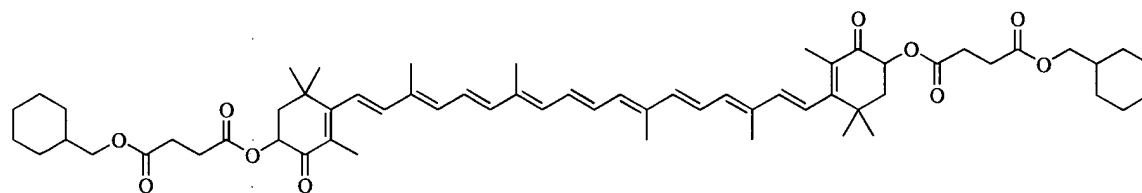
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263. The method of claim 227, wherein the carotenoid derivative having the structure

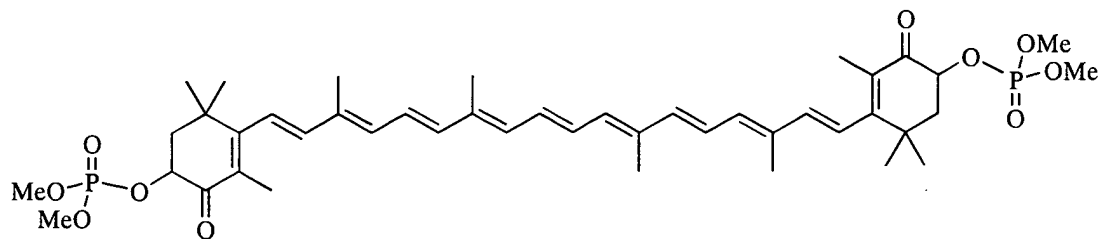


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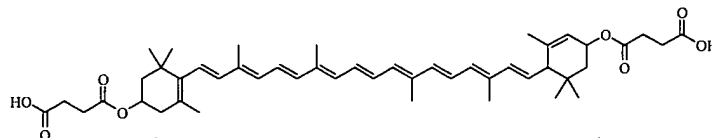
264. The method of claim 227, wherein the carotenoid derivative having the structure



265. The method of claim 227, wherein the carotenoid derivative having the structure

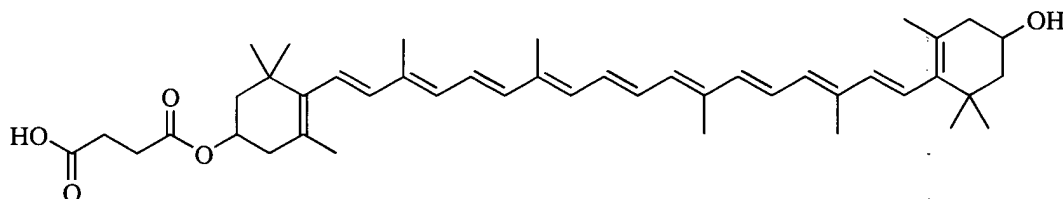


266. The method of claim 227, wherein the carotenoid derivative having the structure

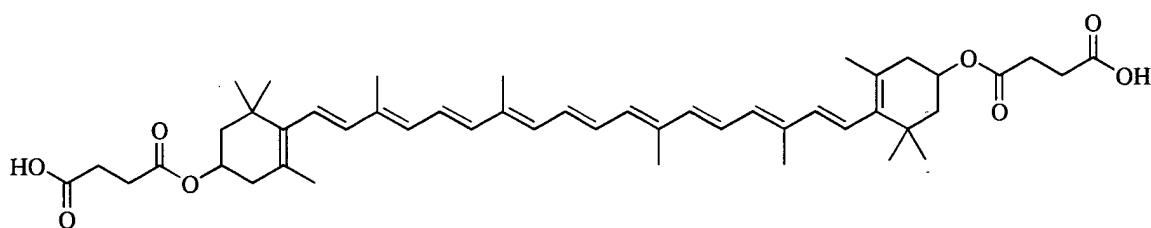


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267. The method of claim 227, wherein the carotenoid derivative having the structure

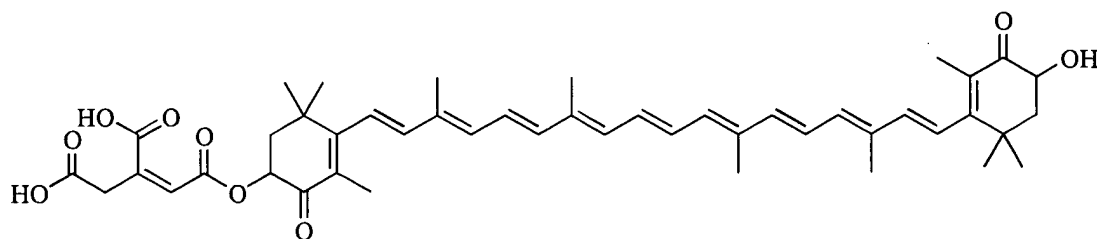


268. The method of claim 227, wherein the carotenoid derivative having the structure



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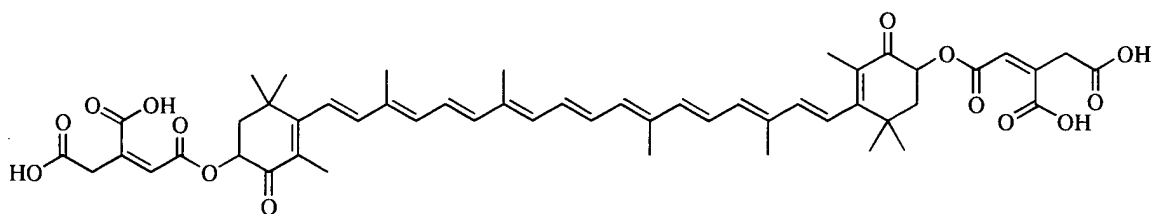
269. The method of claim 227, wherein the carotenoid derivative having the structure



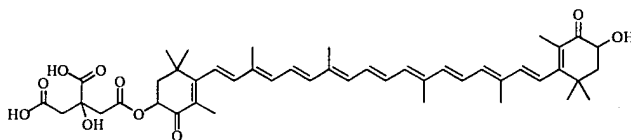
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270. The method of claim 227, wherein the carotenoid derivative having the structure

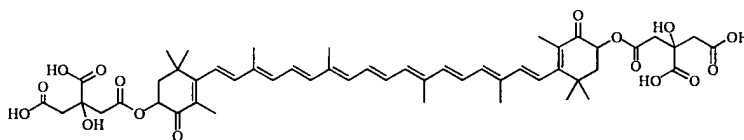


271. The method of claim 227, wherein the carotenoid derivative having the structure

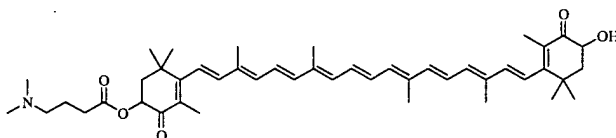


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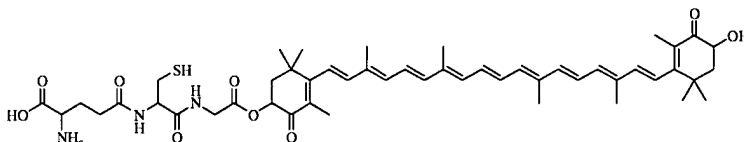
272. The method of claim 227, wherein the carotenoid derivative having the structure



10 273. The method of claim 227, wherein the carotenoid derivative having the structure

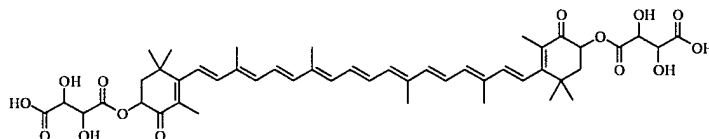


274. The method of claim 227, wherein the carotenoid derivative having the structure

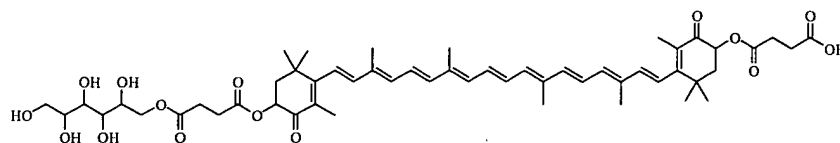


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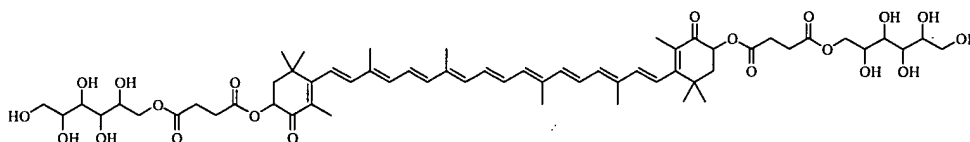
275. The method of claim 227, wherein the carotenoid derivative having the structure



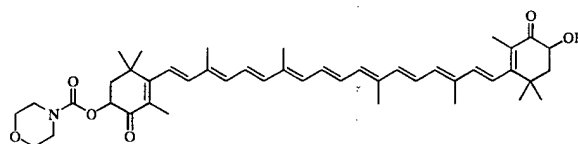
276. The method of claim 227, wherein the carotenoid derivative having the structure



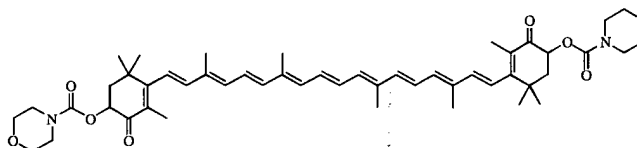
277. The method of claim 227, wherein the carotenoid derivative having the structure



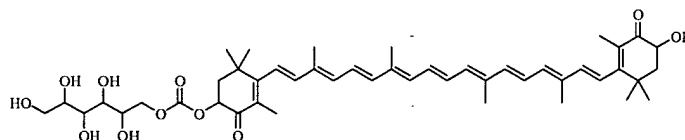
278. The method of claim 227, wherein the carotenoid derivative having the structure



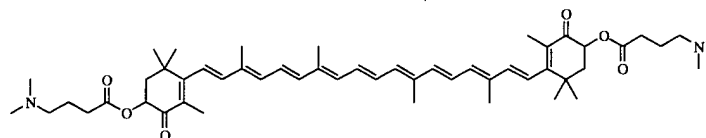
279. The method of claim 227, wherein the carotenoid derivative having the structure



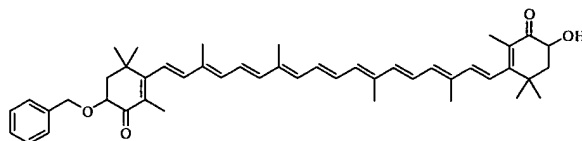
280. The method of claim 227, wherein the carotenoid derivative having the structure



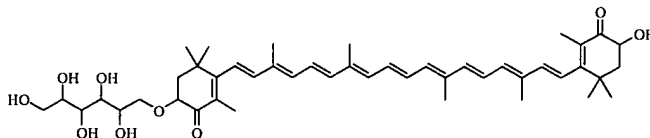
281. The method of claim 227, wherein the carotenoid derivative having the structure



282. The method of claim 227, wherein the carotenoid derivative having the structure

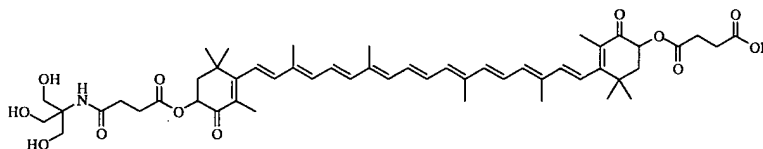


283. The method of claim 227, wherein the carotenoid derivative having the structure

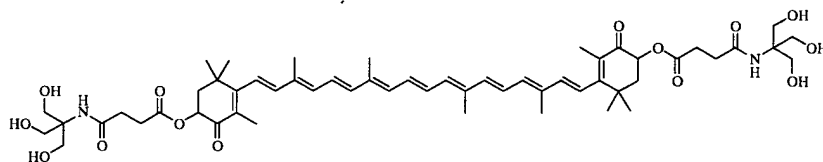


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284. The method of claim 227, wherein the carotenoid derivative having the structure

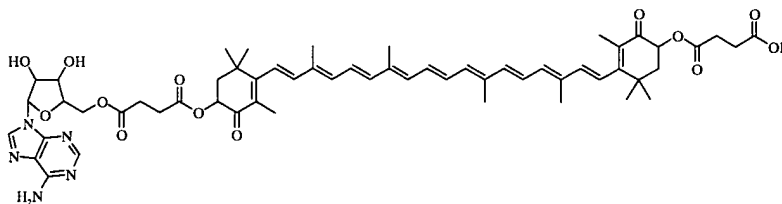


285. The method of claim 227, wherein the carotenoid derivative having the structure

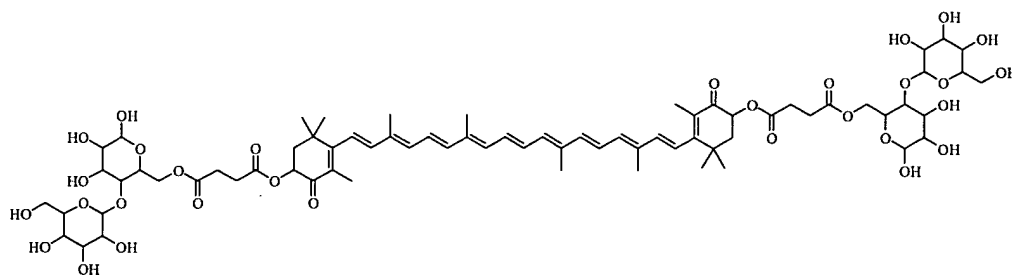


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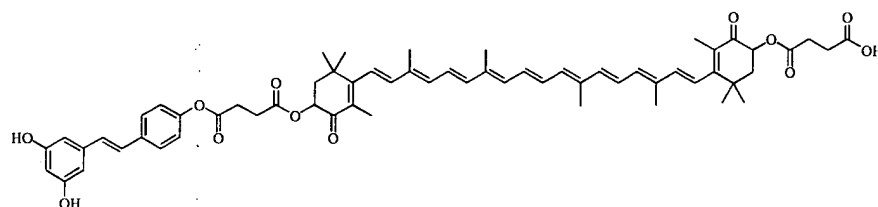
286. The method of claim 227, wherein the carotenoid derivative having the structure



15 287. The method of claim 227, wherein the carotenoid derivative having the structure

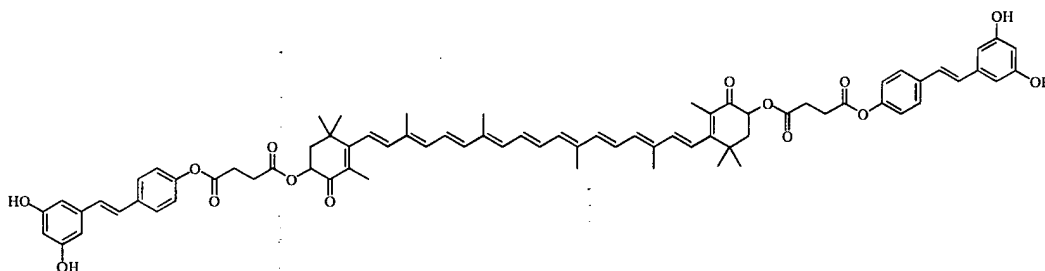


288. The method of claim 227, wherein the carotenoid derivative having the structure



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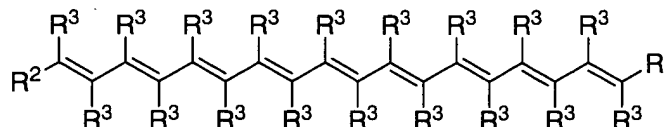
289. The method of claim 227, wherein the carotenoid derivative having the structure



290. A method of treating an ischemia-reperfusion injury with a chemical composition comprising a carotenoid derivative, comprising administering the carotenoid derivative to a subject;

10

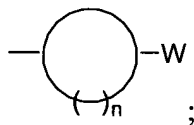
wherein the carotenoid derivative has the structure



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where each R<sup>3</sup> is independently hydrogen or methyl;

where R<sup>1</sup> and R<sup>2</sup> are independently H, an acyclic alkene comprising at least one substituent, or a cyclic ring comprising at least one substituent, wherein the cyclic ring having general structure:



5

where n is 4 to 10 carbon atoms; and

where W is the substituent.

- 10 291. The method of claim 290, wherein each of the substituents –W independently comprises –XR, wherein each X independently comprises O, N, or S.
292. The method of claim 290, wherein each of the substituents –W independently comprises amino acids, esters, carbamates, amides, carbonates, alcohol,  
15 phosphates, or sulfonates.
293. The method of claim 290, wherein the carotenoid derivative is at least partially water soluble.
- 20 294. The method of claim 290, wherein the substituent is at least partially hydrophilic.
295. The method of claim 290, wherein the ischemia-reperfusion injury is associated with myocardial infarction, stroke, peripheral vascular disease, venous or arterial occlusion, deep venous thrombosis, organ transplantation, coronary artery bypass  
25 graft surgery, percutaneous transluminal coronary angioplasty, or cardiovascular arrest and/or death in a mammalian subject.
296. The method of claim 290, wherein the subject is a mammal.

- 30 297. The method of claim 290, wherein the subject is human.

Atty. Dkt. No.: 5777-00201

Meyertons, Hood, Kivlin,  
Kowert & Goetzel, P.C.

298. The method of claim 290, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally.
- 5 299. The method of claim 290, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 5 to 300 mg per day.
- 10 300. The method of claim 290, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 0.25 mg to 1.0 g per day.
- 15 301. The method of claim 290, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject.
- 20 302. The method of claim 290, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 5 to 300 mg per day.
- 25 303. The method of claim 290, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 0.25 mg to 1.0 g per day.
- 30 304. The method of claim 290, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject subcutaneously.
- 30 305. The method of claim 290, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally.

306. The method of claim 290, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 5 to 100 mg per day.

5

307. The method of claim 290, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 0.25 mg to 1.0 g per day.

10 308. The method of claim 290, wherein administering the carotenoid derivative to a subject comprises a dose in a range of about 0.25 mg to 1 g.

309. The method of claim 290, wherein administering the carotenoid derivative to a subject comprises at least two different carotenoid derivatives.

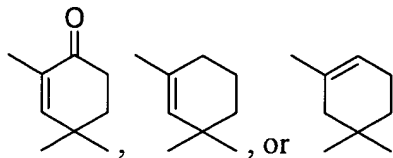
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310. The method of claim 290, wherein the cyclic ring further comprises at least one chiral center.

20

311. The method of claim 290, wherein the cyclic ring further comprises at least one degree of unsaturation.

312. The method of claim 290, wherein each cyclic ring is independently

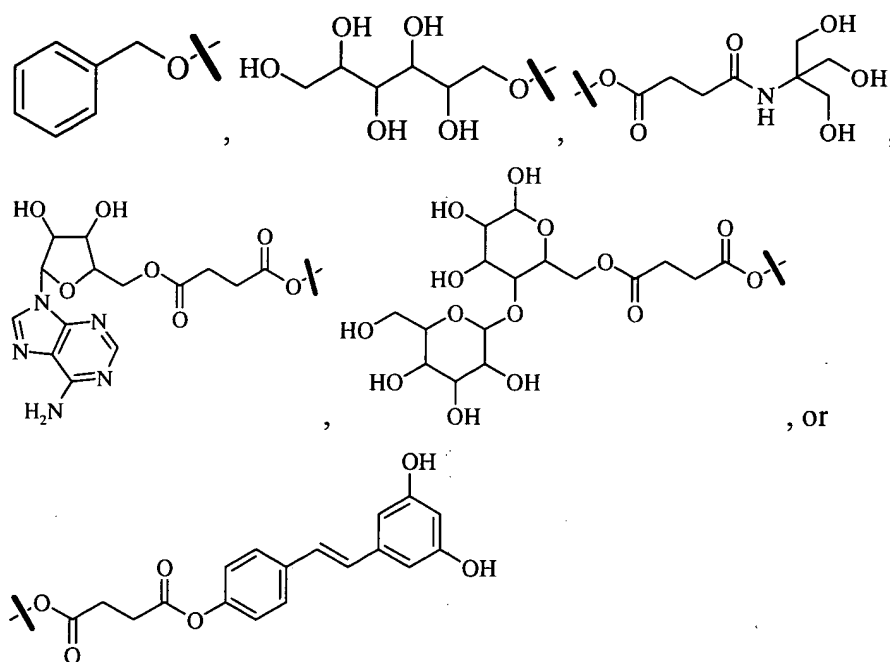


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313. The method of claim 290, wherein the substituent is a carboxylic acid, an ester, an alkanol, an amine, a phosphate, a succinate, a glycinate, an ether, a glucoside, a sugar, or a carboxylate salt.

[illegible]



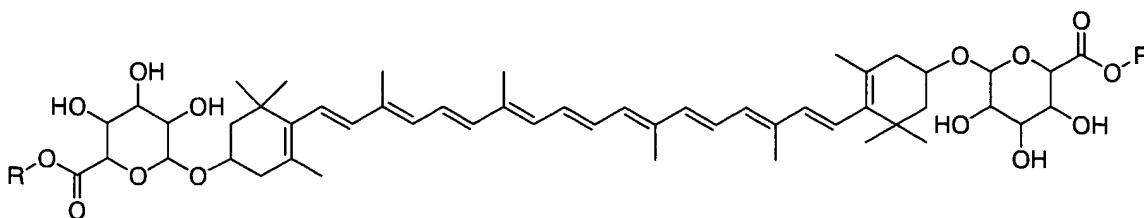


- 5 where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

315. The method of claim 290, wherein the carotenoid derivative is a derivative of a  
10 naturally occurring carotenoid.

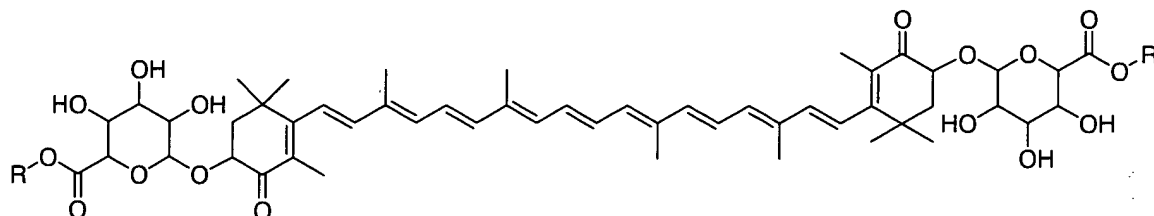
316. The method of claim 290, wherein the carotenoid derivative is a derivative of a  
naturally occurring carotenoid, and wherein the naturally occurring carotenoid is  
lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or  
15 canthaxanthin.

317. The method of claim 290, wherein the carotenoid derivative having the structure



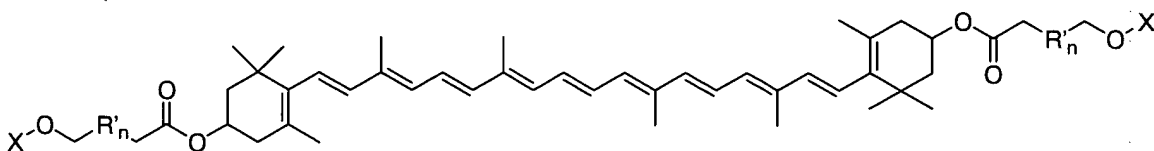
where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

- 5 318. The method of claim 290, wherein the carotenoid derivative having the structure



- where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
10 H, alkyl, or aryl.

319. The method of claim 290, wherein the carotenoid derivative having the structure



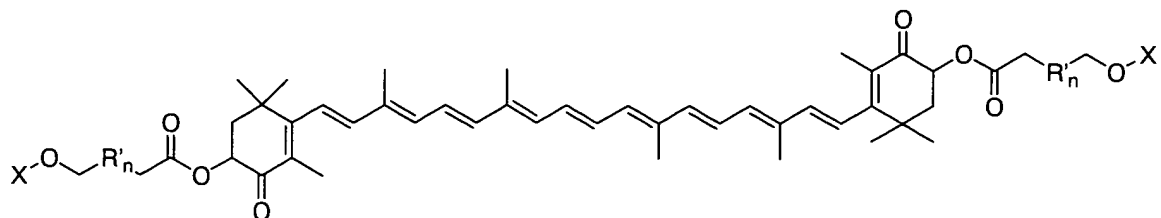
- 15 where each X is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

where each R' is independently -alkyl-O, alkyl, or aryl; and

20

where n is between about 0 and 12.

320. The method of claim 290, wherein the carotenoid derivative having the structure

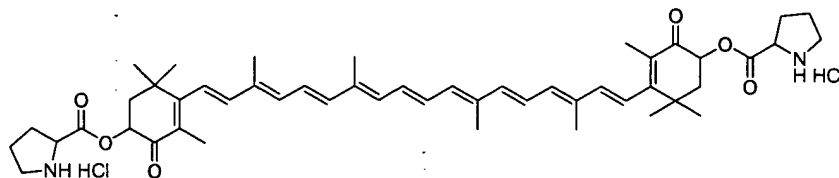


where each X is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
 5 H, alkyl, or aryl;

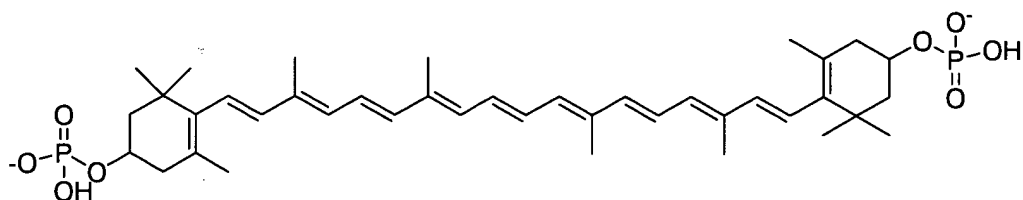
where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

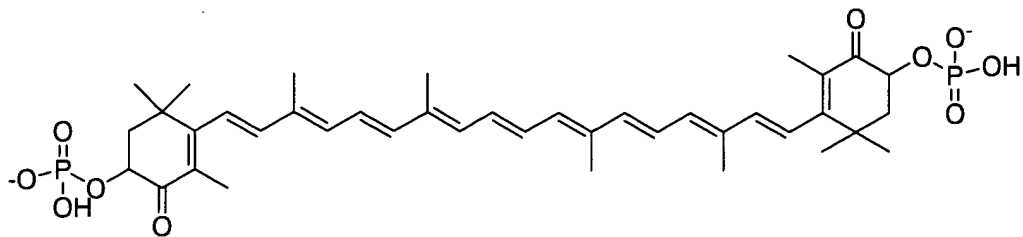
10 321. The method of claim 290, wherein the carotenoid derivative having the structure



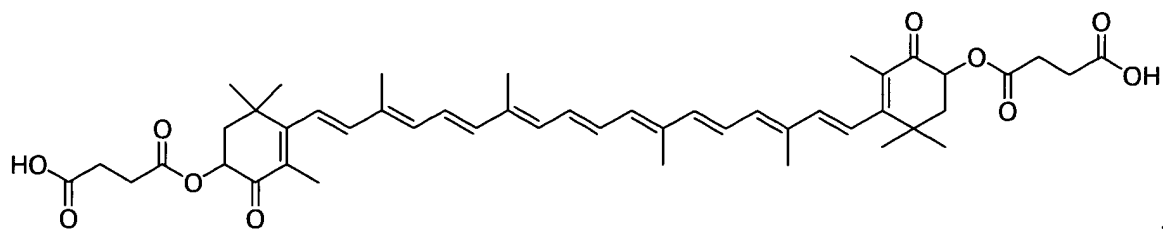
322. The method of claim 290, wherein the carotenoid derivative having the structure



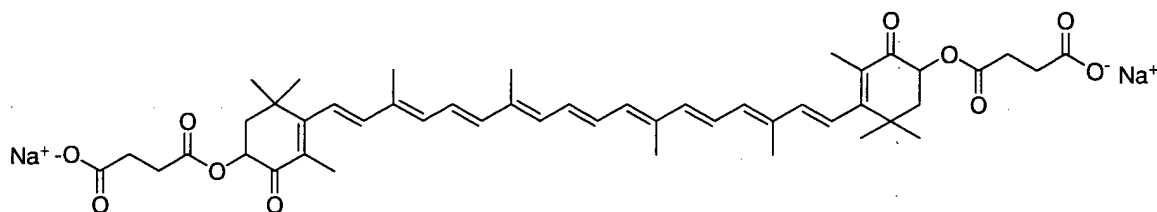
15 323. The method of claim 290, wherein the carotenoid derivative having the structure



324. The method of claim 290, wherein the carotenoid derivative having the structure

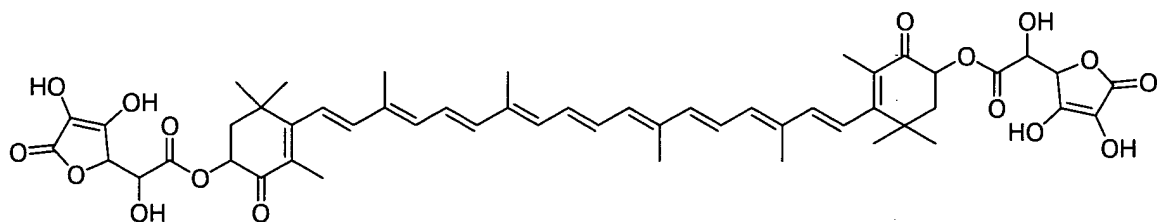


325. The method of claim 290, wherein the carotenoid derivative having the structure



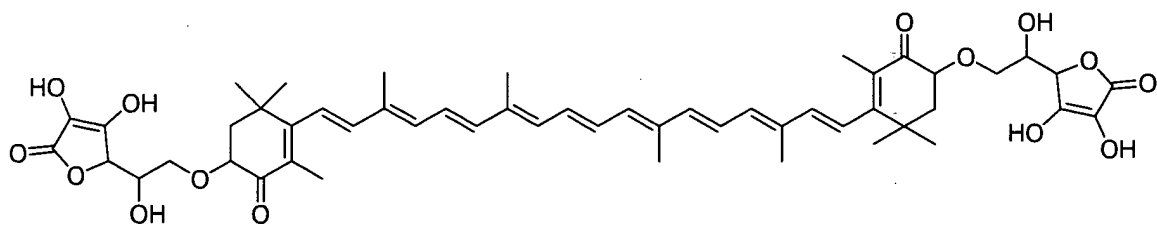
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326. The method of claim 290, wherein the carotenoid derivative having the structure

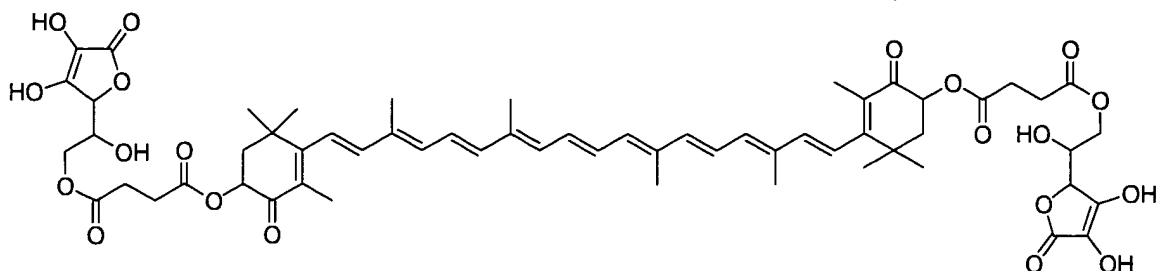


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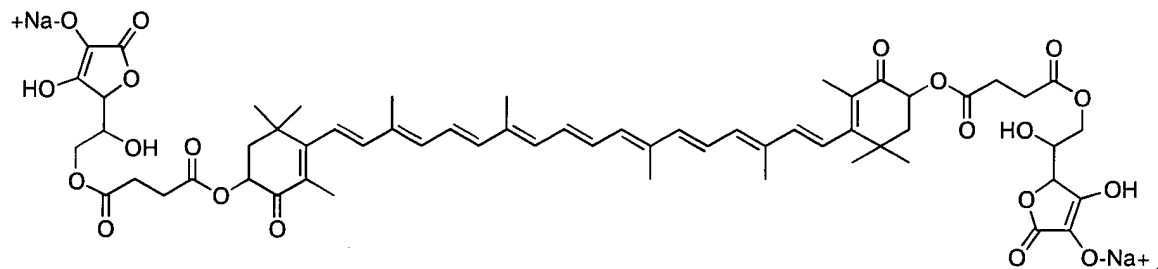
327. The method of claim 290, wherein the carotenoid derivative having the structure



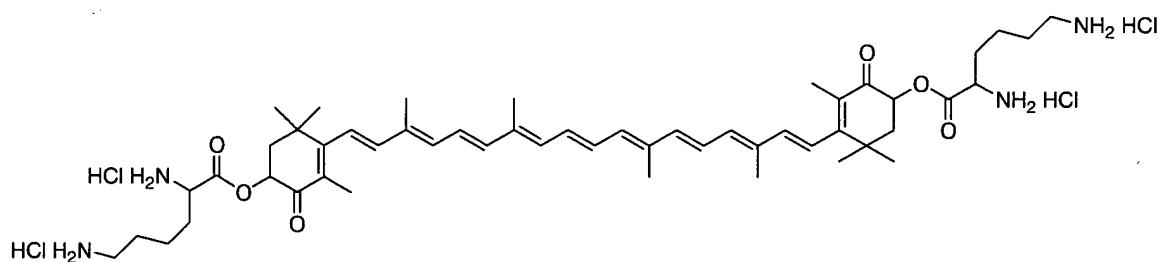
328. The method of claim 290, wherein the carotenoid derivative having the structure



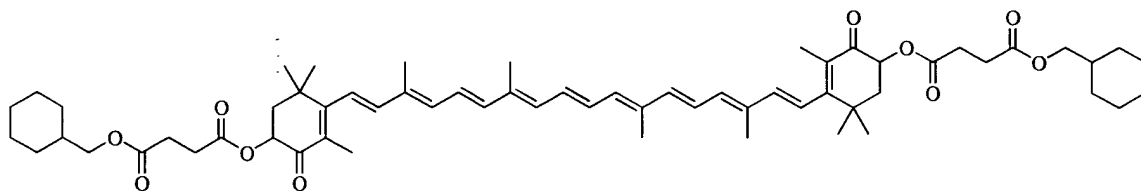
329. The method of claim 290, wherein the carotenoid derivative having the structure



330. The method of claim 290, wherein the carotenoid derivative having the structure

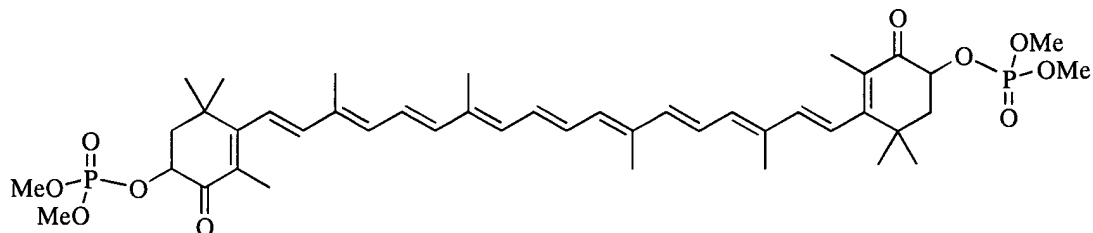


331. The method of claim 290, wherein the carotenoid derivative having the structure

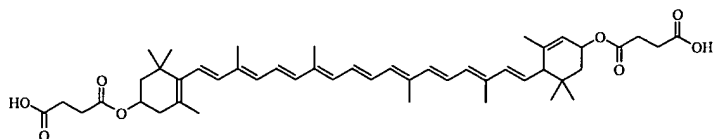


10

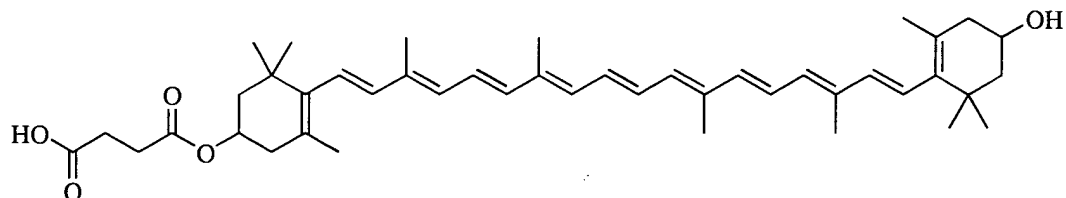
332. The method of claim 290, wherein the carotenoid derivative having the structure



333. The method of claim 290, wherein the carotenoid derivative having the structure

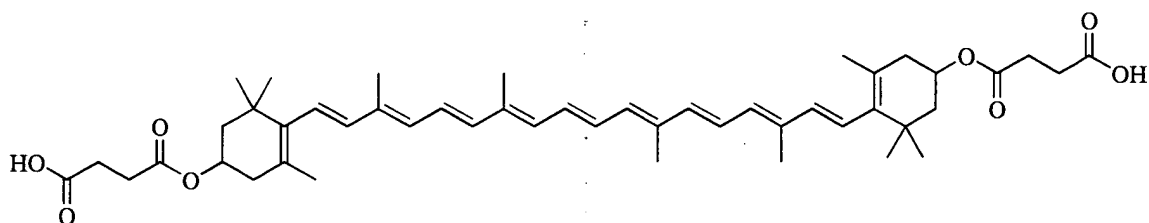


334. The method of claim 290, wherein the carotenoid derivative having the structure

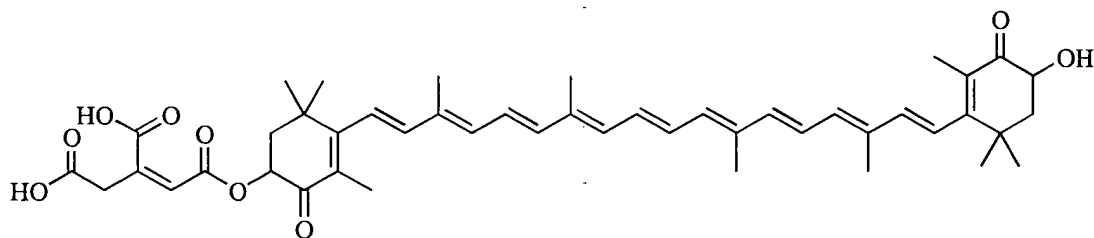


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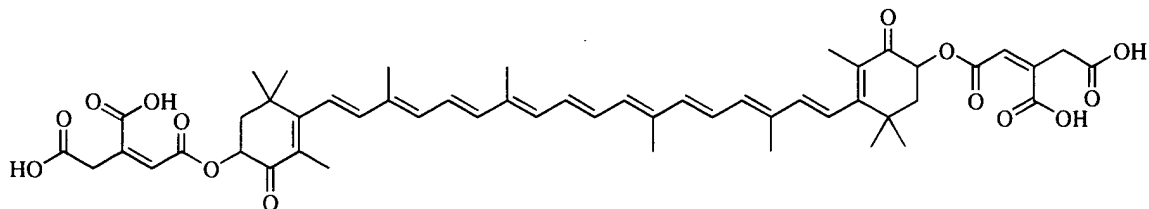
335. The method of claim 290, wherein the carotenoid derivative having the structure



10 336. The method of claim 290, wherein the carotenoid derivative having the structure

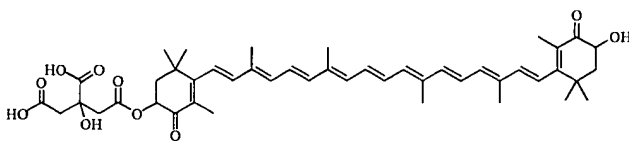


337. The method of claim 290, wherein the carotenoid derivative having the structure

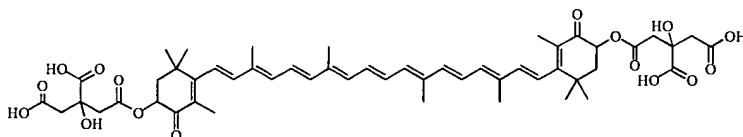


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338. The method of claim 290, wherein the carotenoid derivative having the structure

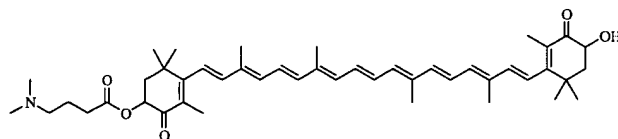


339. The method of claim 290, wherein the carotenoid derivative having the structure

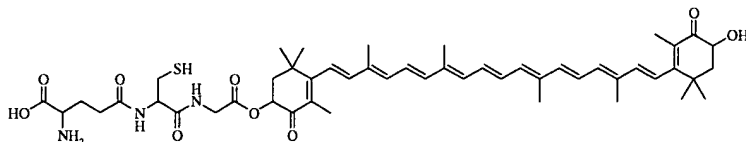


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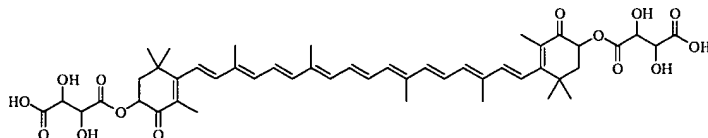
340. The method of claim 290, wherein the carotenoid derivative having the structure



10 341. The method of claim 290, wherein the carotenoid derivative having the structure

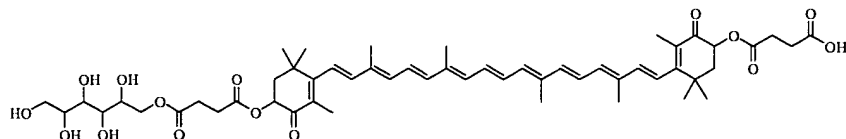


342. The method of claim 290, wherein the carotenoid derivative having the structure

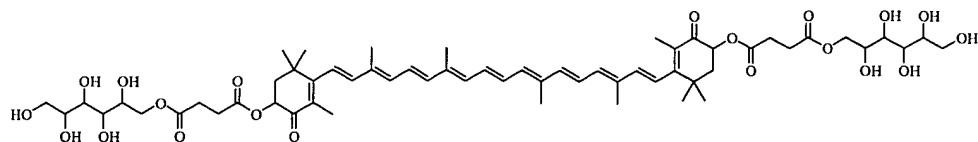


15

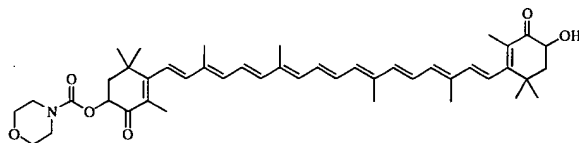
343. The method of claim 290, wherein the carotenoid derivative having the structure



344. The method of claim 290, wherein the carotenoid derivative having the structure

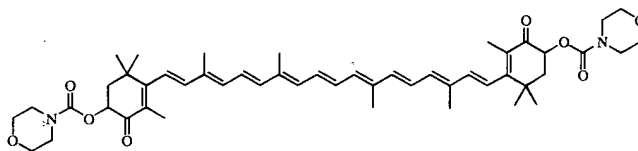


345. The method of claim 290, wherein the carotenoid derivative having the structure

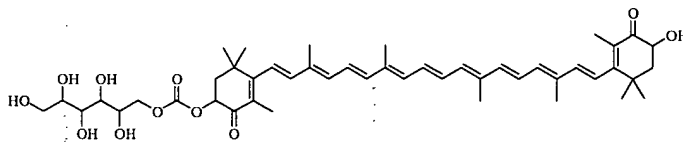


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346. The method of claim 290, wherein the carotenoid derivative having the structure

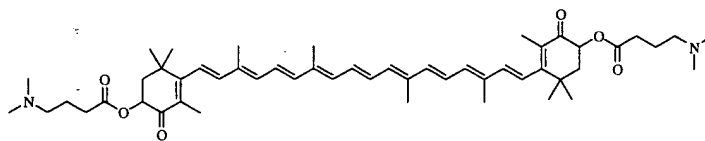


347. The method of claim 290, wherein the carotenoid derivative having the structure



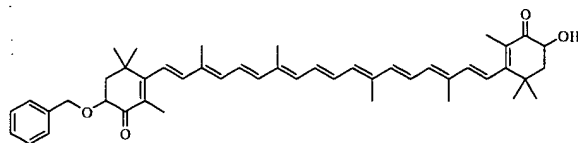
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348. The method of claim 290, wherein the carotenoid derivative having the structure



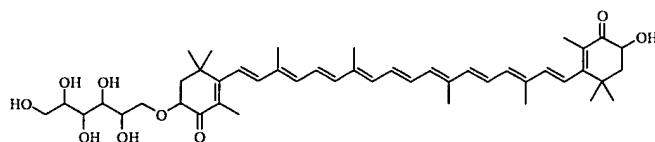
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349. The method of claim 290, wherein the carotenoid derivative having the structure

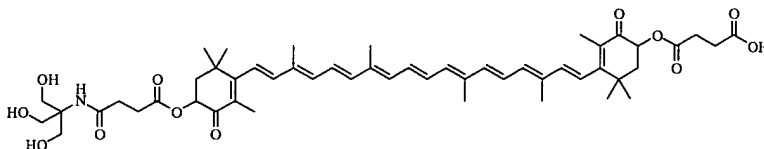


350. The method of claim 290, wherein the carotenoid derivative having the structure



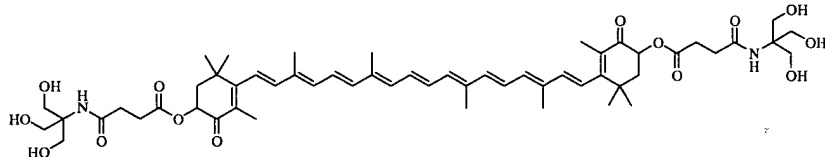


351. The method of claim 290, wherein the carotenoid derivative having the structure

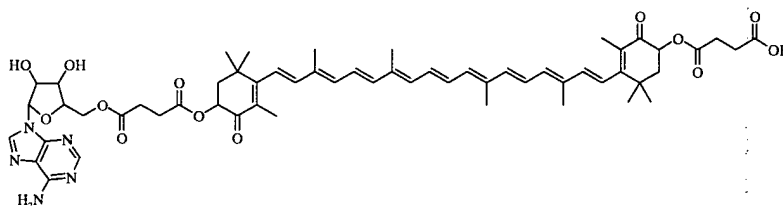


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352. The method of claim 290, wherein the carotenoid derivative having the structure

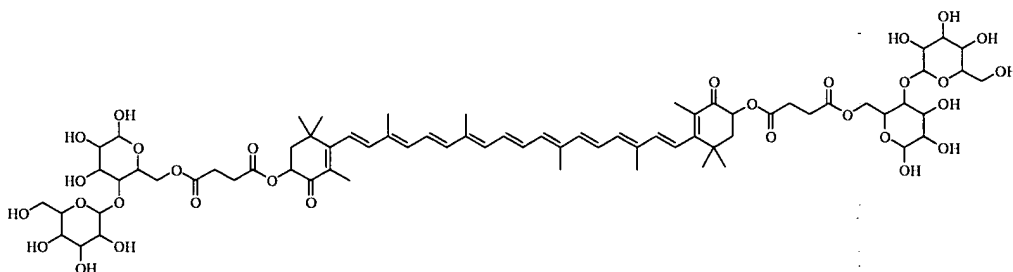


353. The method of claim 290, wherein the carotenoid derivative having the structure

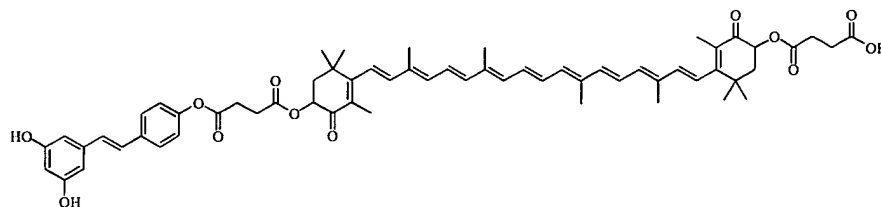


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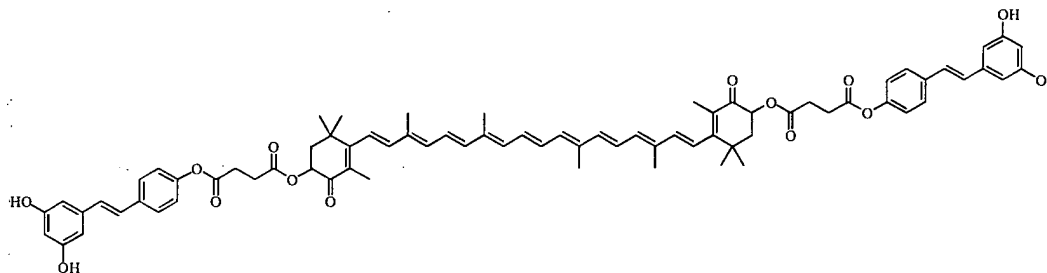
354. The method of claim 290, wherein the carotenoid derivative having the structure



15 355. The method of claim 290, wherein the carotenoid derivative having the structure



356. The method of claim 290, wherein the carotenoid derivative having the structure

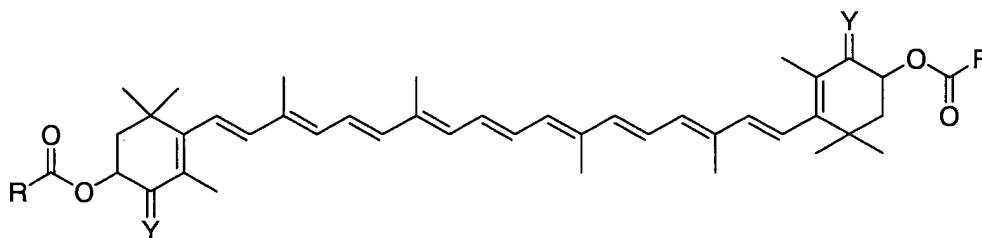


5

357. A method of treating an ischemia-reperfusion injury with a chemical composition comprising a carotenoid derivative, comprising administering the carotenoid derivative to a subject;

10

wherein the carotenoid derivative has the structure



where each Y is independently O or H<sub>2</sub>;

15

where each R is independently OR<sup>1</sup> or R<sup>1</sup>;

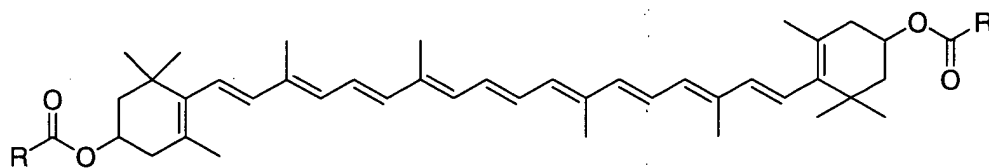
where each R<sup>1</sup> is independently -alkyl-NR<sub>3</sub><sup>2+</sup>, -aromatic-NR<sub>3</sub><sup>2+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

20

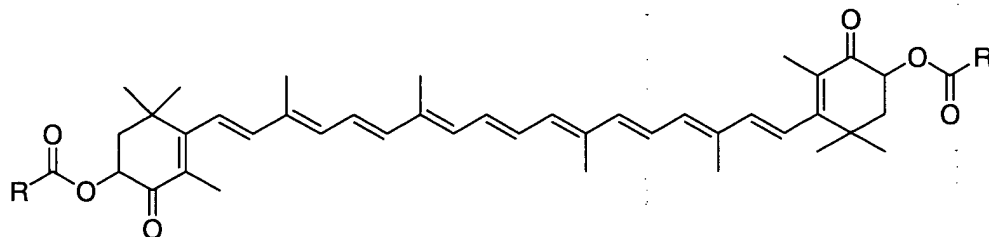
where each R<sup>2</sup> is independently H, alkyl, or aryl.

358. The method of claim 357, wherein the carotenoid derivative is at least partially  
5 water soluble.

359. The method of claim 357, wherein Y is H<sub>2</sub>, the carotenoid derivative having the  
structure



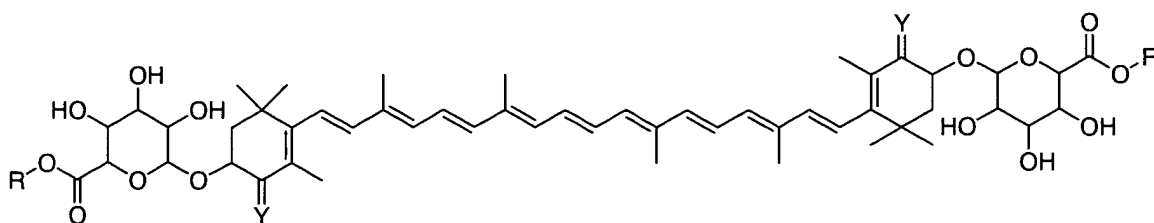
360. The method of claim 357, wherein Y is O, the carotenoid derivative having the  
structure



361. The method of claim 357, wherein the carotenoid derivative further comprises at  
least one chiral center.

362. A method of treating an ischemia-reperfusion injury with a chemical composition  
20 comprising a carotenoid derivative, comprising administering the carotenoid  
derivative to a subject;

wherein the carotenoid derivative has the structure

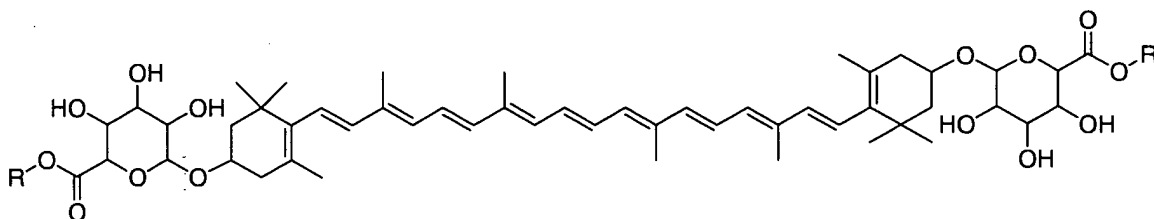


where each Y is independently O or H<sub>2</sub>;

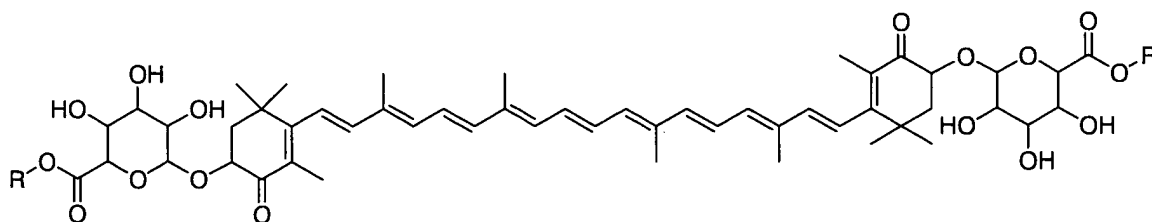
5 where each R is independently H, alkyl, or aryl.

363. The method of claim 362, wherein the carotenoid derivative is at least partially water soluble.

10 364. The method of claim 362, wherein Y is H<sub>2</sub>, the carotenoid derivative having the structure



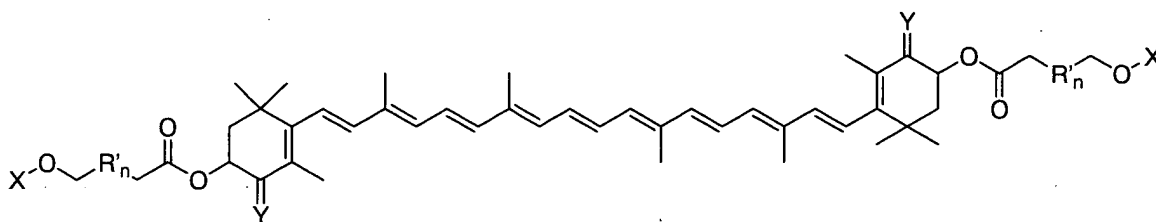
15 365. The method of claim 362, wherein Y is O, the carotenoid derivative having the structure



366. The method of claim 362, wherein the carotenoid derivative further comprises at least one chiral center.

367. A method of treating an ischemia-reperfusion injury with a chemical composition comprising a carotenoid derivative, comprising administering the carotenoid derivative to a subject;

5 wherein the carotenoid derivative has the structure



where each Y is independently O or H<sub>2</sub>;

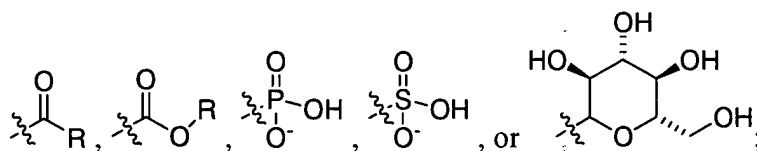
10

where R' is CH<sub>2</sub>;

where n is 1 to 9;

15

where each X is independently

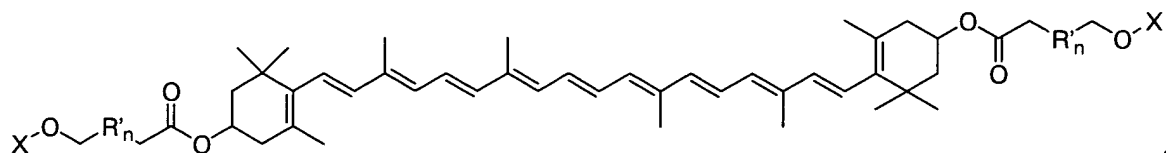


where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>,  
20 polyethylene glycol, dextran, H, alkyl, or aryl;

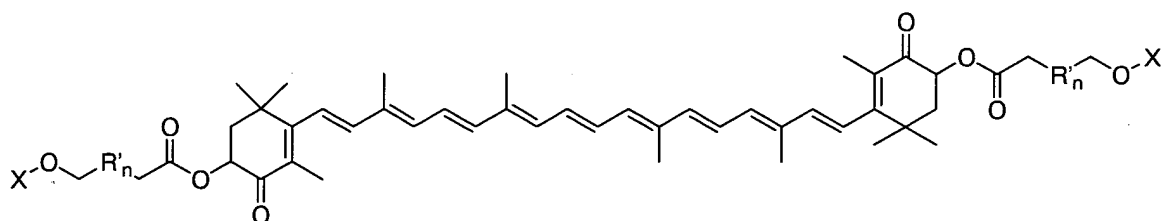
where each R<sup>1</sup> is independently H, alkyl, or aryl.

368. The method of claim 367, wherein the carotenoid derivative is at least partially  
25 water soluble.

369. The method of claim 367, wherein Y is H<sub>2</sub>, the carotenoid derivative having the structure



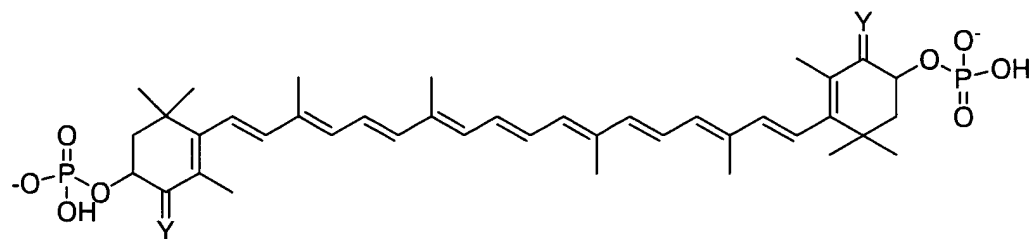
370. The method of claim 367, wherein Y is O, the carotenoid derivative having the structure



371. The method of claim 367, wherein the carotenoid derivative further comprises at least one chiral center.

372. A method of treating an ischemia-reperfusion injury with a chemical composition comprising a carotenoid derivative, comprising administering the carotenoid derivative to a subject;

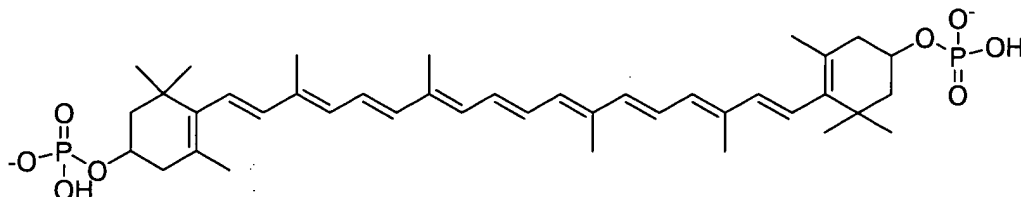
wherein the carotenoid derivative has the structure



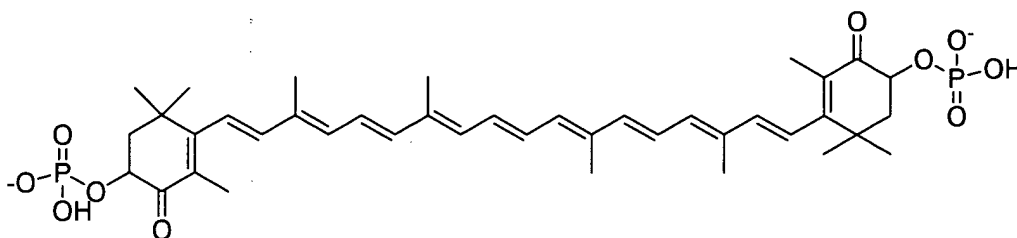
where each Y is independently O or H<sub>2</sub>.

373. The method of claim 372, wherein the carotenoid derivative is at least partially water soluble.

374. The method of claim 372, wherein Y is H<sub>2</sub>, the carotenoid derivative having the structure



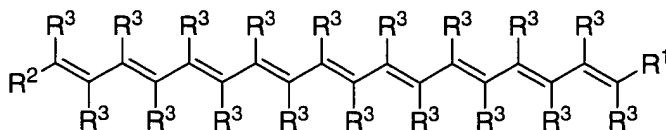
375. The method of claim 372, wherein Y is O, the carotenoid derivative having the structure



376. The method of claim 372, wherein the carotenoid derivative further comprises at least one chiral center.

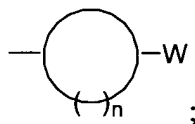
377. A method of treating an ischemia-reperfusion injury with a chemical composition comprising a carotenoid derivative, comprising intracoronary administration of the carotenoid derivative to a subject;

wherein the carotenoid derivative has the structure



where each R<sup>3</sup> is independently hydrogen or methyl;

where R<sup>1</sup> and R<sup>2</sup> are independently H, an acyclic alkene comprising at least one substituent, or a cyclic ring comprising at least one substituent, wherein the cyclic ring having general structure:



where n is 4 to 10 carbon atoms; and

where W is the substituent.

10 378. The method of claim 377, wherein each of the substituents -W independently comprises -XR, wherein each X independently comprises O, N, or S.

15 379. The method of claim 377, wherein each of the substituents -W independently comprises amino acids, esters, carbamates, amides, carbonates, alcohol, phosphates, or sulfonates.

380. The method of claim 377, wherein the carotenoid derivative is at least partially water soluble.

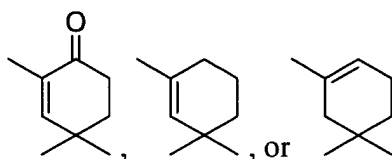
20 381. The method of claim 377, wherein the substituent is at least partially hydrophilic.

25 382. The method of claim 377, wherein the ischemia-reperfusion injury is associated with myocardial infarction, stroke, peripheral vascular disease, venous or arterial occlusion, deep venous thrombosis, organ transplantation, coronary artery bypass graft surgery, percutaneous transluminal coronary angioplasty, or cardiovascular arrest and/or death in a mammalian subject.

30 383. The method of claim 377, wherein the subject is a mammal.

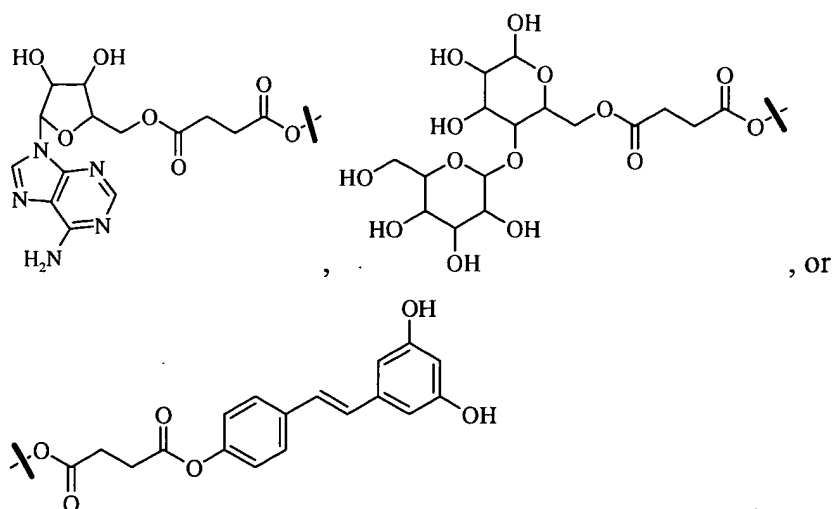


384. The method of claim 377, wherein the subject is human.
385. The method of claim 377, wherein intracoronary administration of the carotenoid derivative to a subject comprises a dose of about 5 mg to 300 mg per day.
- 5 386. The method of claim 377, wherein intracoronary administration of the carotenoid derivative to a subject comprises a dose of about 0.25 mg to 1.0 g per day.
387. The method of claim 377, wherein administering the carotenoid derivative to a  
10 subject comprises at least two different carotenoid derivatives.
388. The method of claim 377, wherein the cyclic ring further comprises at least one chiral center.
- 15 389. The method of claim 377, wherein the cyclic ring further comprises at least one degree of unsaturation.
390. The method of claim 377, wherein each cyclic ring is independently



391. The method of claim 377, wherein the substituent is a carboxylic acid, an ester, an alkanol, an amine, a phosphate, a succinate, a glycinate, an ether, a glucoside, a sugar, or a carboxylate salt.
- 25 392. The method of claim 377, wherein each substituent is independently



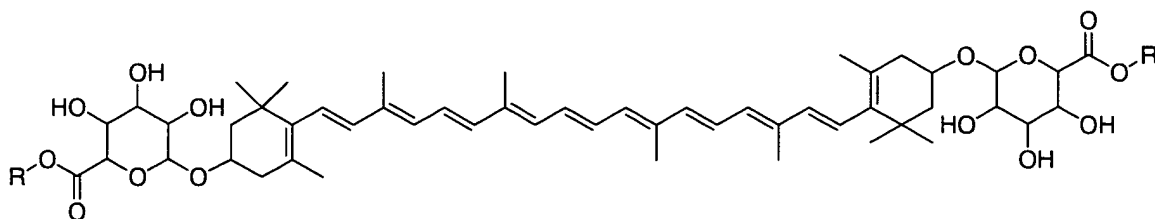


where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

393. The method of claim 377, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid.

394. The method of claim 377, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid, and wherein the naturally occurring carotenoid is lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or canthaxanthin.

395. The method of claim 377, wherein the carotenoid derivative having the structure

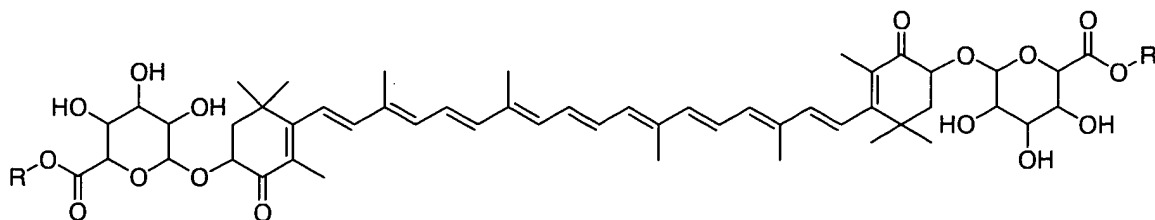


where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

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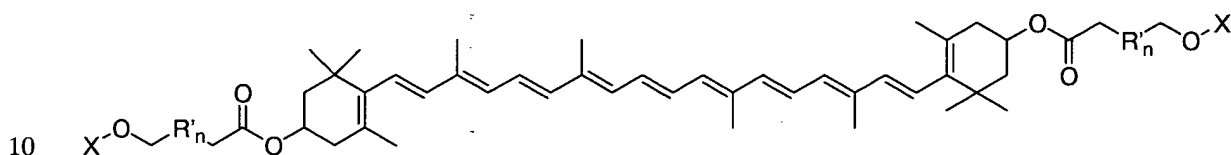
Meyertons, Hood, Kivlin,  
Kowert & Goetzel, P.C.

396. The method of claim 377, wherein the carotenoid derivative having the structure



5 where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

397. The method of claim 377, wherein the carotenoid derivative having the structure



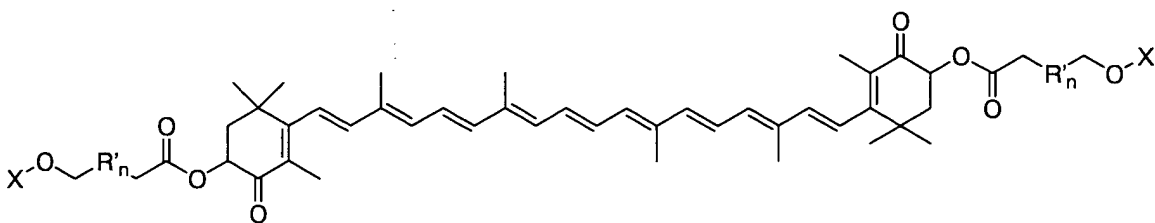
where each X is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

15

where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

20 398. The method of claim 377, wherein the carotenoid derivative having the structure

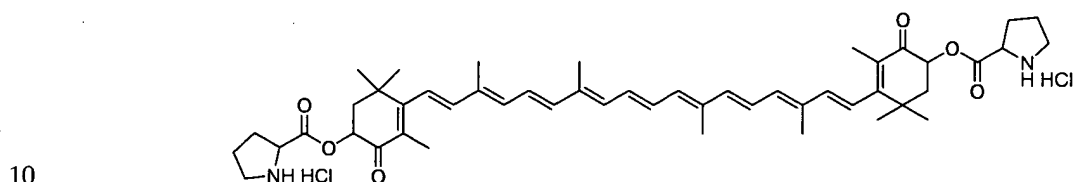


where each X is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

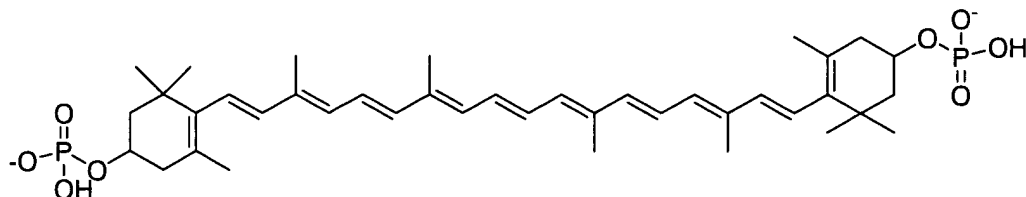
5 where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

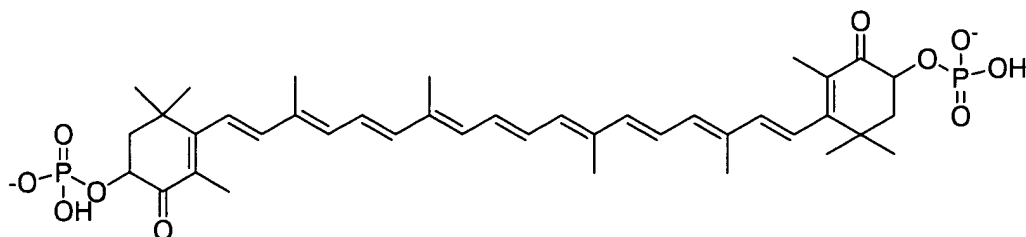
399. The method of claim 377, wherein the carotenoid derivative having the structure



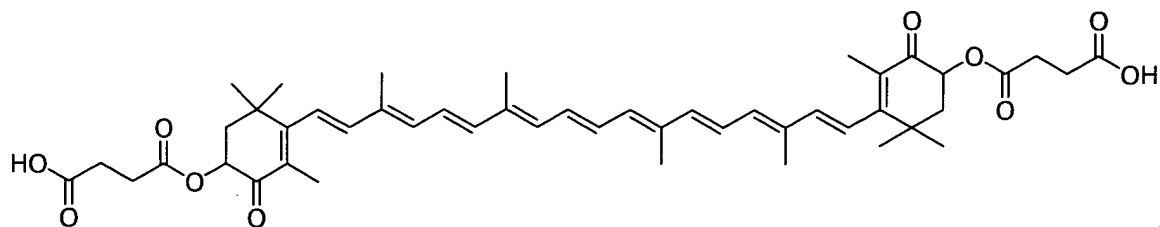
400. The method of claim 377, wherein the carotenoid derivative having the structure



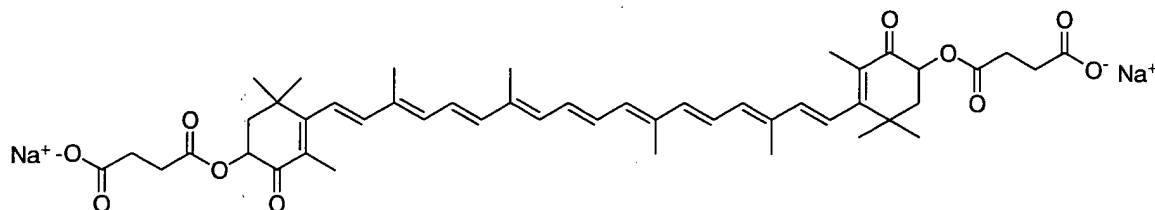
15 401. The method of claim 377, wherein the carotenoid derivative having the structure



402. The method of claim 377, wherein the carotenoid derivative having the structure

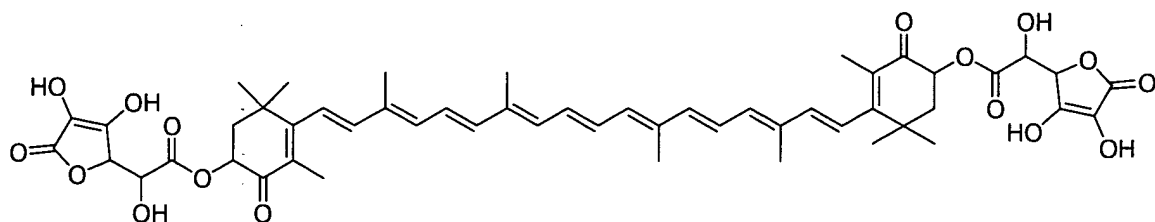


403. The method of claim 377, wherein the carotenoid derivative having the structure

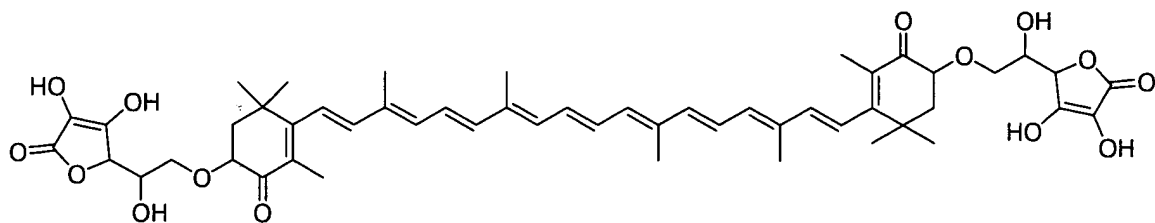


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404. The method of claim 377, wherein the carotenoid derivative having the structure

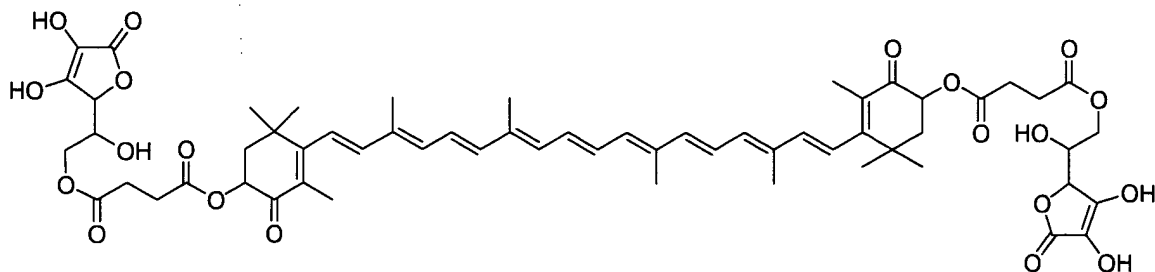


405. The method of claim 377, wherein the carotenoid derivative having the structure

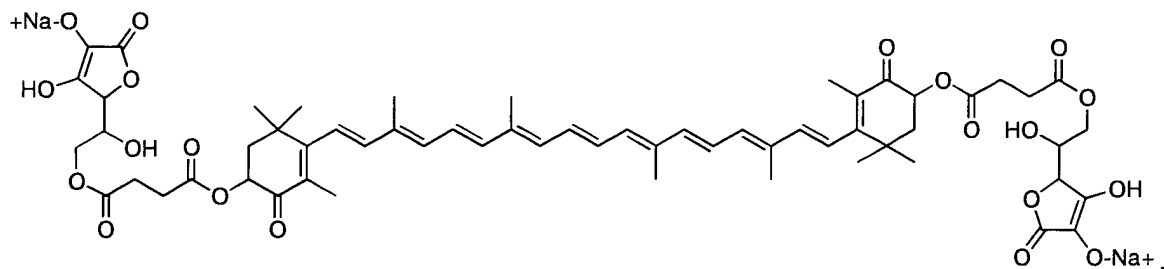


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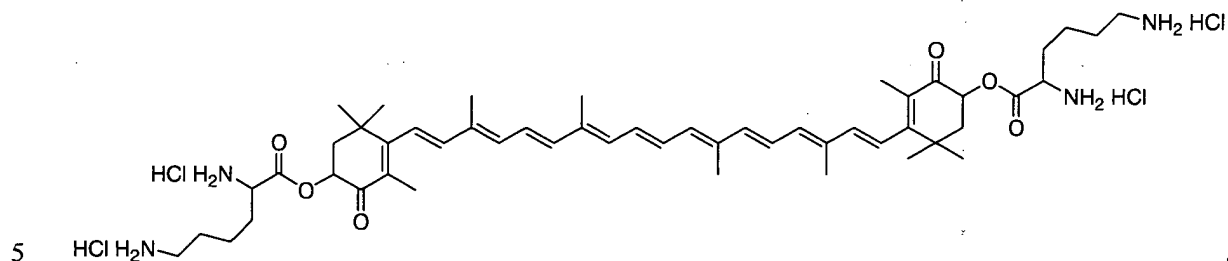
406. The method of claim 377, wherein the carotenoid derivative having the structure



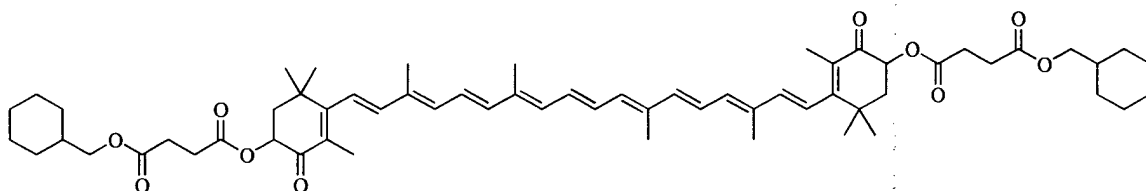
407. The method of claim 377, wherein the carotenoid derivative having the structure



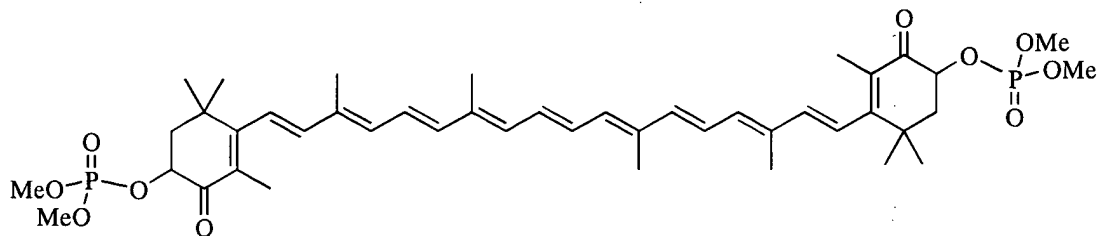
408. The method of claim 377, wherein the carotenoid derivative having the structure



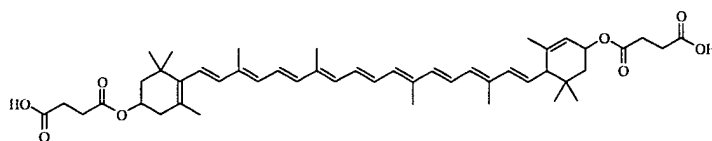
409. The method of claim 377, wherein the carotenoid derivative having the structure



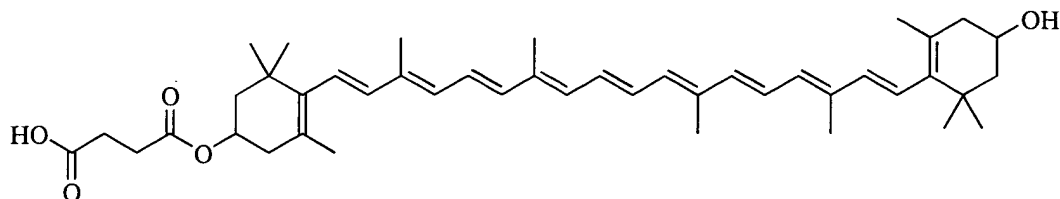
10 410. The method of claim 377, wherein the carotenoid derivative having the structure



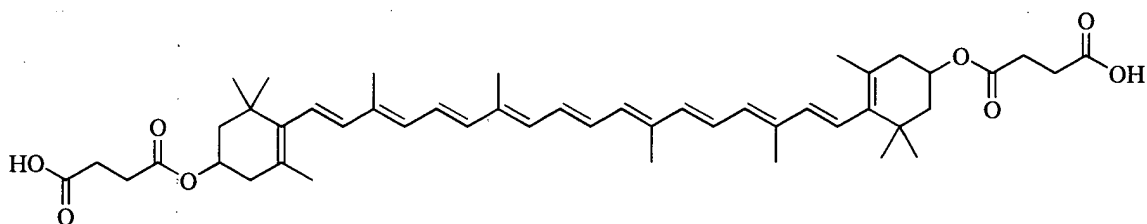
411. The method of claim 377, wherein the carotenoid derivative having the structure



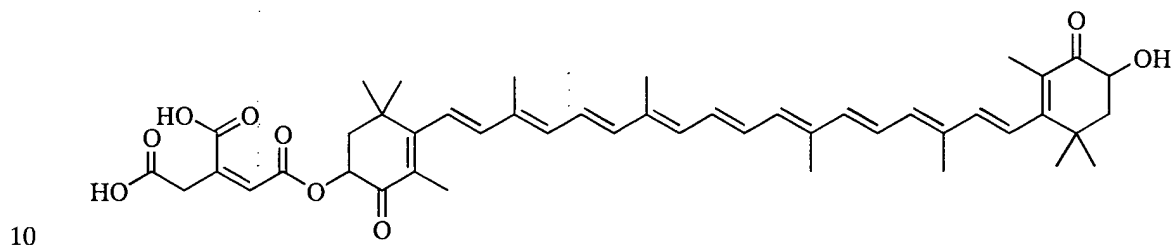
412. The method of claim 377, wherein the carotenoid derivative having the structure



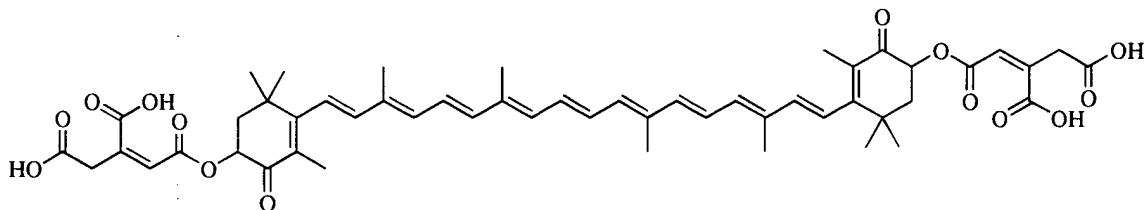
5 413. The method of claim 377, wherein the carotenoid derivative having the structure



414. The method of claim 377, wherein the carotenoid derivative having the structure

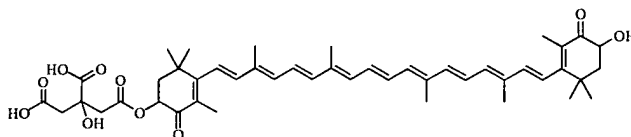


415. The method of claim 377, wherein the carotenoid derivative having the structure

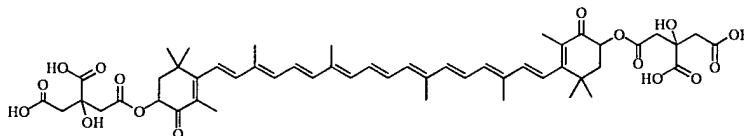


15 416. The method of claim 377, wherein the carotenoid derivative having the structure



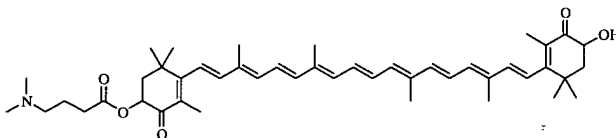


417. The method of claim 377, wherein the carotenoid derivative having the structure

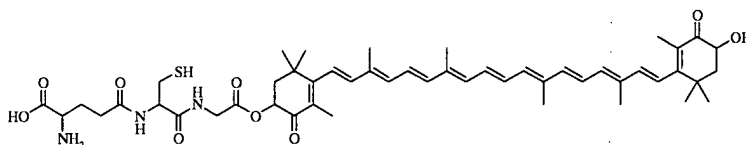


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418. The method of claim 377, wherein the carotenoid derivative having the structure

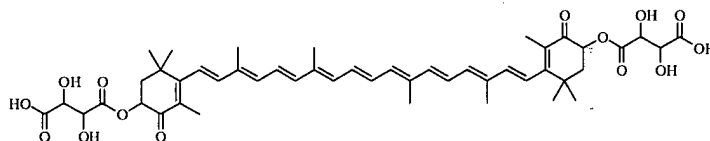


419. The method of claim 377, wherein the carotenoid derivative having the structure



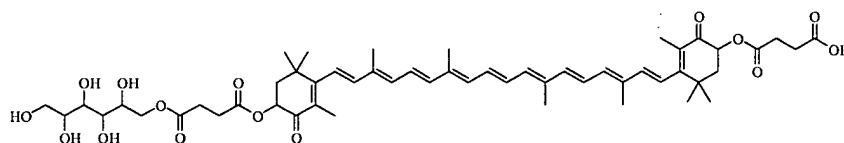
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420. The method of claim 377, wherein the carotenoid derivative having the structure

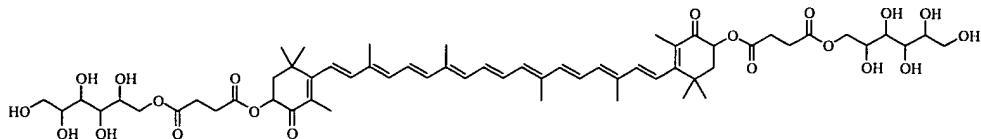


15

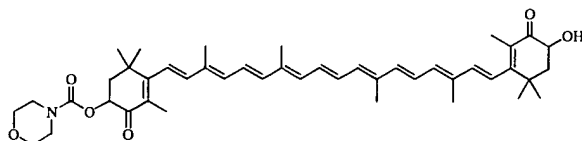
421. The method of claim 377, wherein the carotenoid derivative having the structure



422. The method of claim 377, wherein the carotenoid derivative having the structure

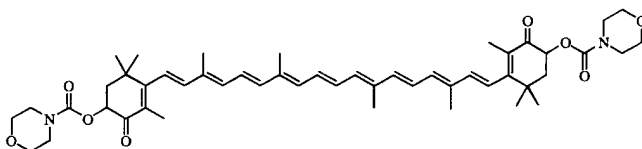


423. The method of claim 377, wherein the carotenoid derivative having the structure

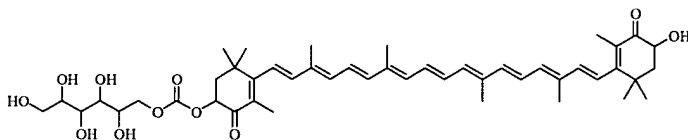


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424. The method of claim 377, wherein the carotenoid derivative having the structure

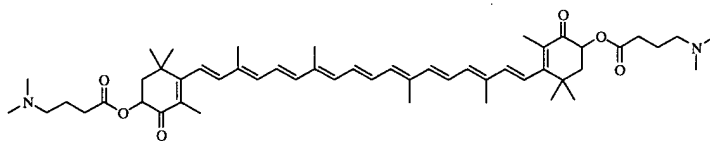


425. The method of claim 377, wherein the carotenoid derivative having the structure

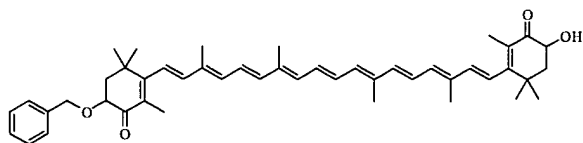


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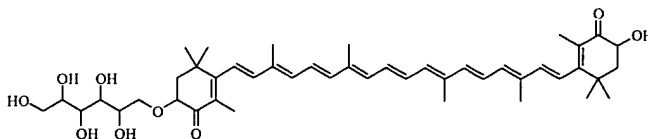
426. The method of claim 377, wherein the carotenoid derivative having the structure



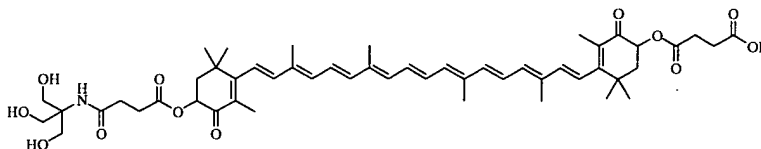
15 427. The method of claim 377, wherein the carotenoid derivative having the structure



428. The method of claim 377, wherein the carotenoid derivative having the structure

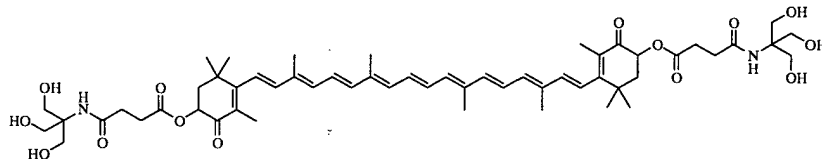


429. The method of claim 377, wherein the carotenoid derivative having the structure

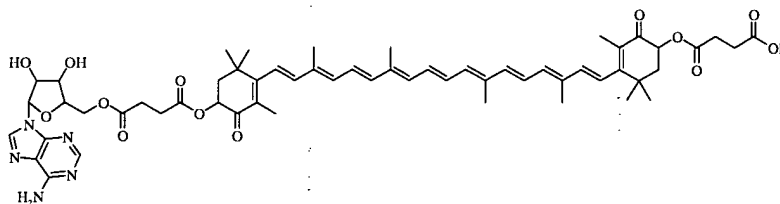


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430. The method of claim 377, wherein the carotenoid derivative having the structure

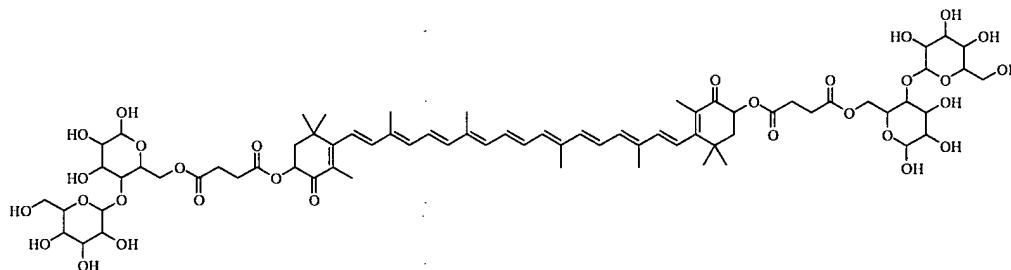


431. The method of claim 377, wherein the carotenoid derivative having the structure

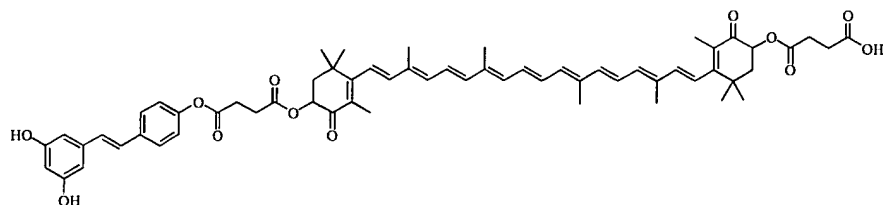


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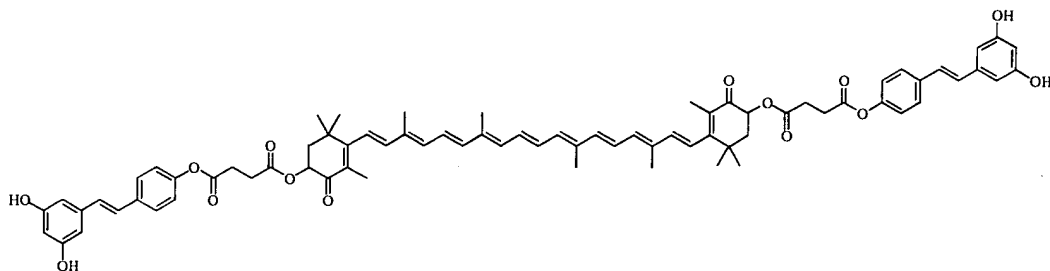
432. The method of claim 377, wherein the carotenoid derivative having the structure



15 433. The method of claim 377, wherein the carotenoid derivative having the structure



434. The method of claim 377, wherein the carotenoid derivative having the structure

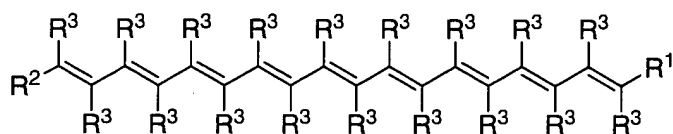


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435. A method of treating a liver disease with a chemical composition comprising a carotenoid derivative, comprising administering the carotenoid derivative to a subject;

10

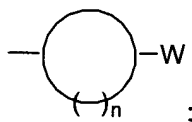
wherein the carotenoid derivative has the structure



where each  $R^3$  is independently hydrogen or methyl;

15

where  $R^1$  and  $R^2$  are independently H, an acyclic alkene comprising at least one substituent, or a cyclic ring comprising at least one substituent, wherein the cyclic ring having general structure:



20

where n is 4 to 10 carbon atoms; and

where W is the substituent.

- 5     436.    The method of claim 435, wherein each of the substituents –W independently  
         comprises –XR, wherein each X independently comprises O, N, or S.
437.    The method of claim 435, wherein each of the substituents –W independently  
         comprises amino acids, esters, carbamates, amides, carbonates, alcohol,  
10       phosphates, or sulfonates.
438.    The method of claim 435, wherein the carotenoid derivative is at least partially  
         water soluble.
- 15     439.    The method of claim 435, wherein the substituent is at least partially hydrophilic.
440.    The method of claim 435, wherein the liver disease is associated with Hepatitis C.
441.    The method of claim 435, wherein the subject is a mammal.
- 20     442.    The method of claim 435, wherein the subject is human.
443.    The method of claim 435, wherein administering the carotenoid derivative to a  
         subject comprises administering the carotenoid derivative to a subject  
25       parenterally.
444.    The method of claim 435, wherein administering the carotenoid derivative to a  
         subject comprises administering the carotenoid derivative to a subject parenterally  
         at a dose of about 5 to 300 mg per day.
- 30

445. The method of claim 435, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 0.25 mg to 1.0 g per day.
- 5 446. The method of claim 435, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject.
- 10 447. The method of claim 435, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 5 to 300 mg per day.
- 15 448. The method of claim 435, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 0.25 mg to 1.0 g per day.
- 20 449. The method of claim 435, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject subcutaneously.
- 25 450. The method of claim 435, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally.
- 30 451. The method of claim 435, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 5 to 100 mg per day.
452. The method of claim 435, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 0.25 mg to 1.0 g per day.

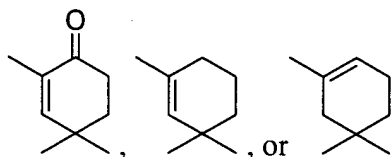
453. The method of claim 435, wherein administering the carotenoid derivative to a subject comprises a dose in a range of about 0.25 mg to 1 g.

454. The method of claim 435, wherein administering the carotenoid derivative to a subject comprises at least two different carotenoid derivatives.

455. The method of claim 435, wherein the cyclic ring further comprises at least one chiral center.

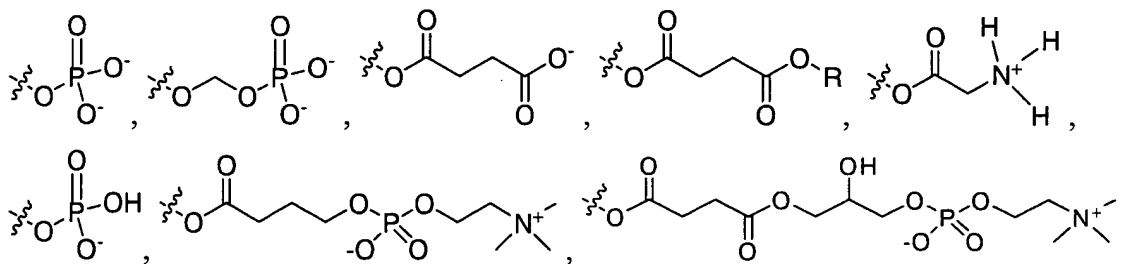
456. The method of claim 435, wherein the cyclic ring further comprises at least one degree of unsaturation.

457. The method of claim 435, wherein each cyclic ring is independently



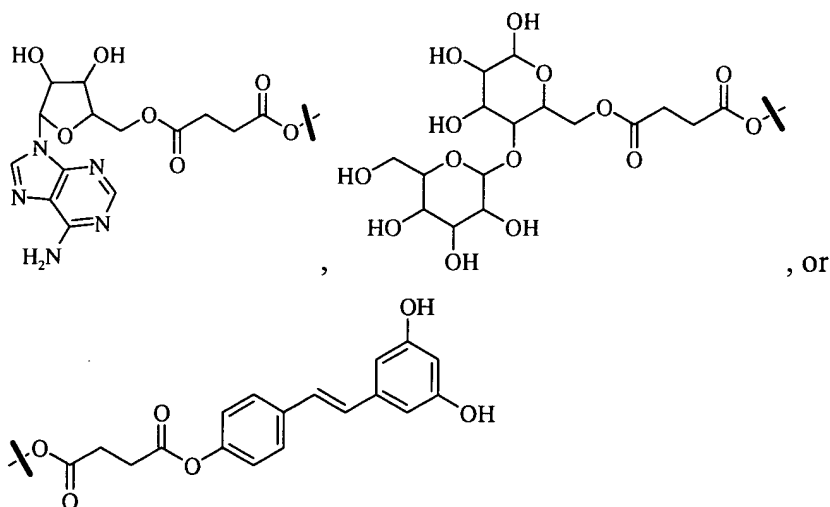
458. The method of claim 435, wherein the substituent is a carboxylic acid, an ester, an alkanol, an amine, a phosphate, a succinate, a glycinate, an ether, a glucoside, a sugar, or a carboxylate salt.

459. The method of claim 435, wherein each substituent is independently







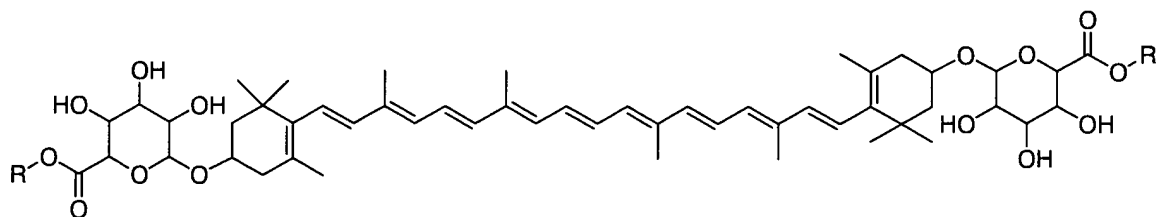


where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

460. The method of claim 435, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid.

461. The method of claim 435, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid, and wherein the naturally occurring carotenoid is lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or canthaxanthin.

462. The method of claim 435, wherein the carotenoid derivative having the structure

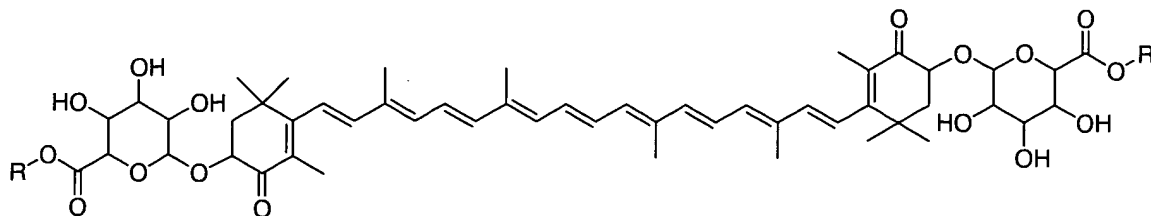


where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

Atty. Dkt. No.: 5777-00201

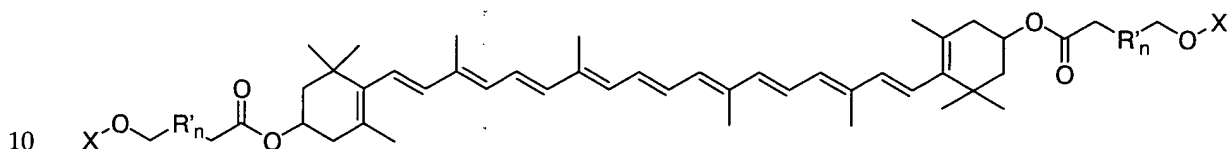
Meyertons, Hood, Kivlin,  
Kowert & Goetzl, P.C.

463. The method of claim 435, wherein the carotenoid derivative having the structure



5 where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

464. The method of claim 435, wherein the carotenoid derivative having the structure

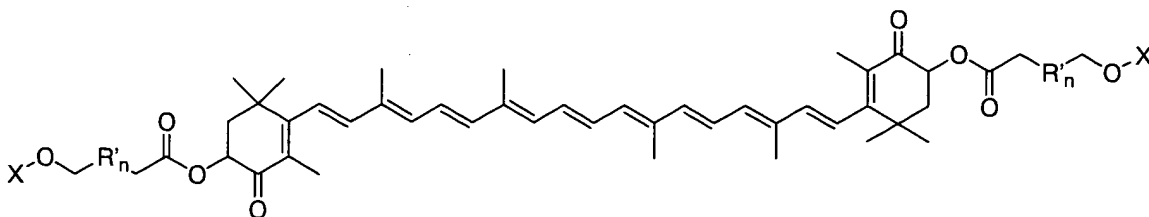


where each X is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

15 where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

20 465. The method of claim 435, wherein the carotenoid derivative having the structure

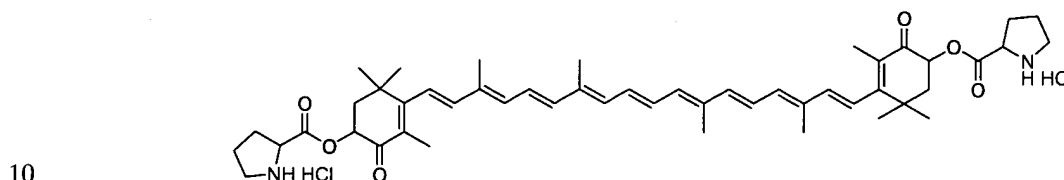


where each X is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

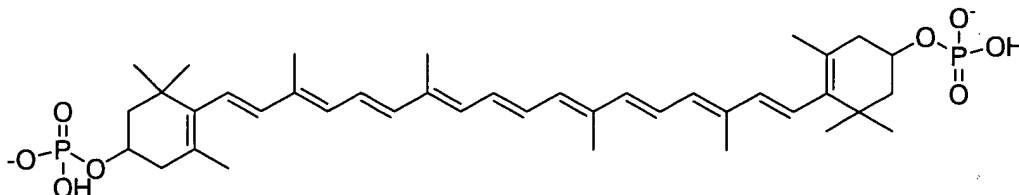
5 where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

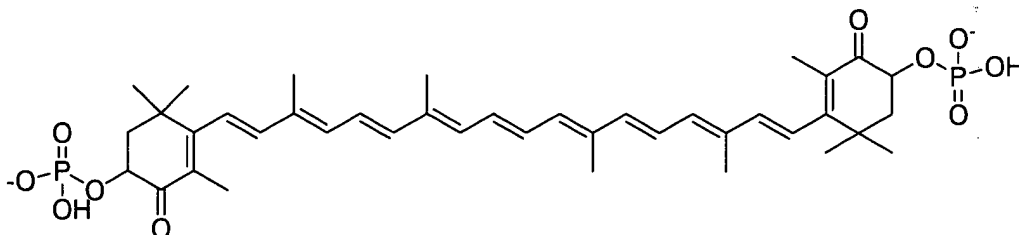
466. The method of claim 435, wherein the carotenoid derivative having the structure



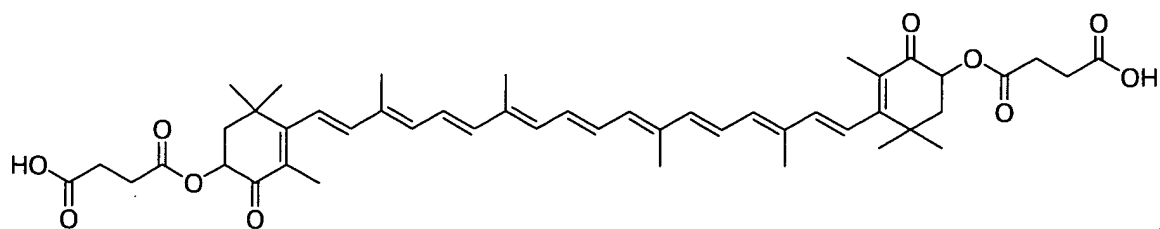
467. The method of claim 435, wherein the carotenoid derivative having the structure



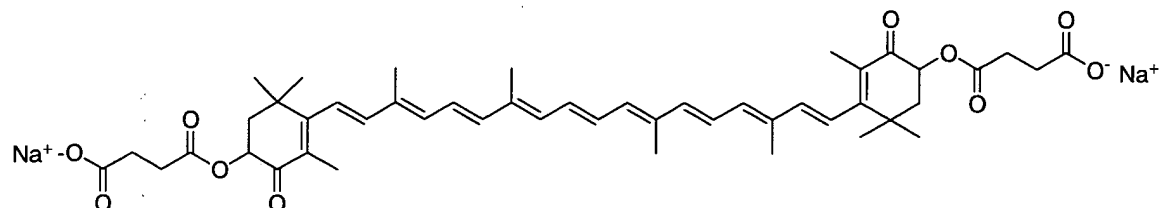
15 468. The method of claim 435, wherein the carotenoid derivative having the structure



469. The method of claim 435, wherein the carotenoid derivative having the structure

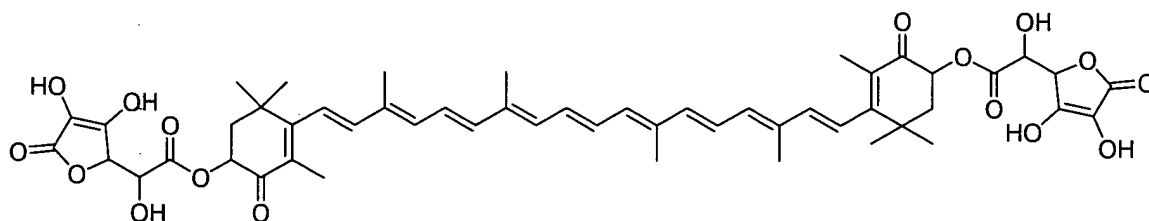


470. The method of claim 435, wherein the carotenoid derivative having the structure

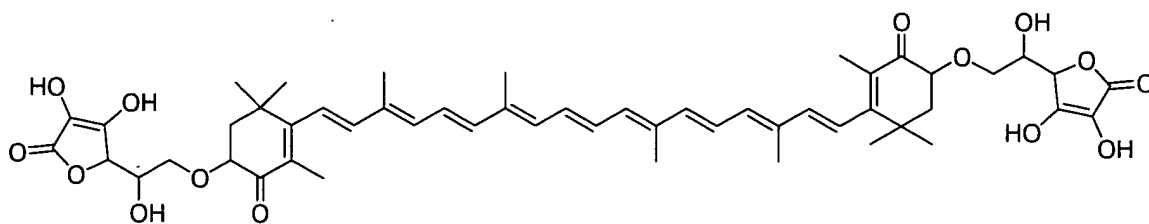


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471. The method of claim 435, wherein the carotenoid derivative having the structure

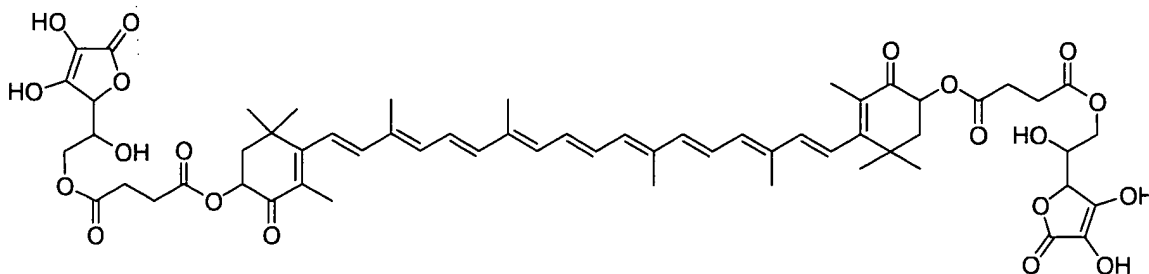


472. The method of claim 435, wherein the carotenoid derivative having the structure

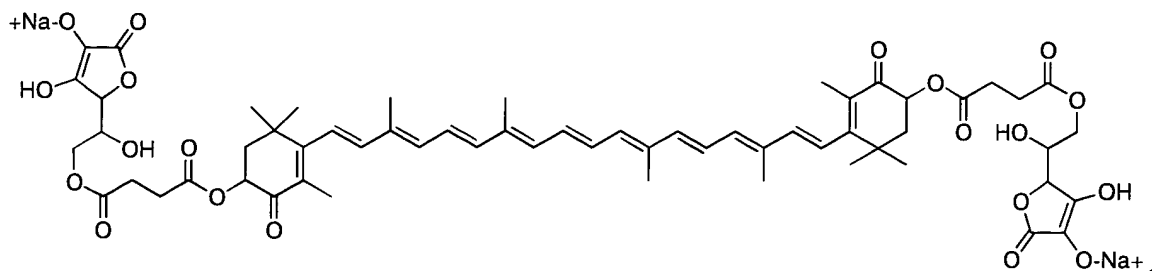


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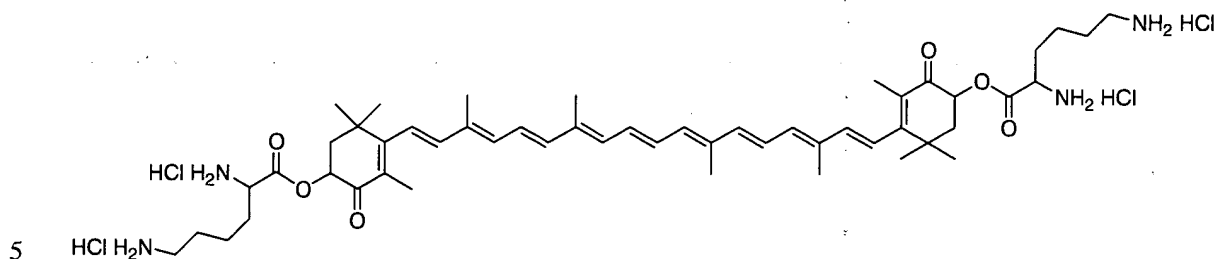
473. The method of claim 435, wherein the carotenoid derivative having the structure



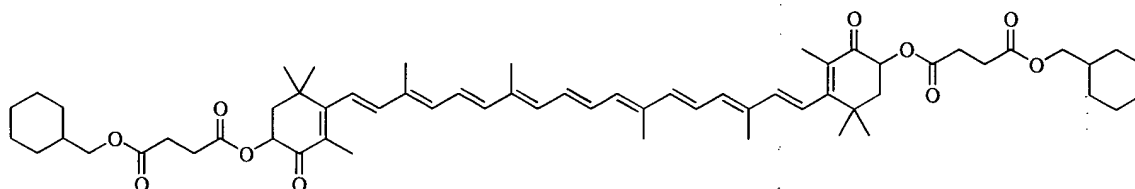
474. The method of claim 435, wherein the carotenoid derivative having the structure



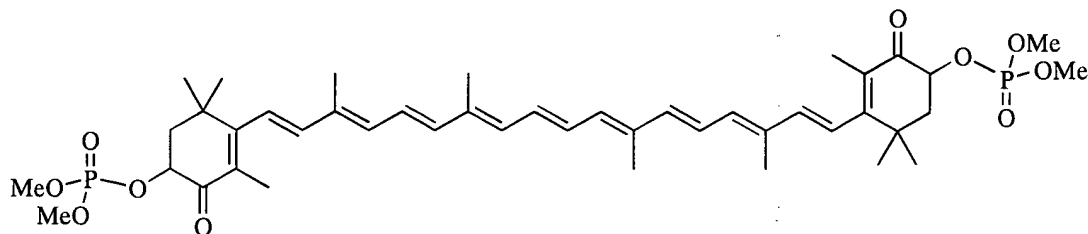
475. The method of claim 435, wherein the carotenoid derivative having the structure



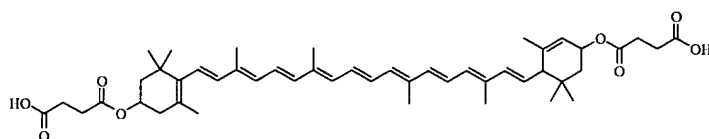
476. The method of claim 435, wherein the carotenoid derivative having the structure



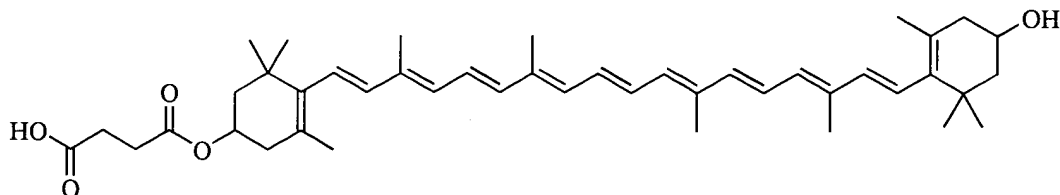
10 477. The method of claim 435, wherein the carotenoid derivative having the structure



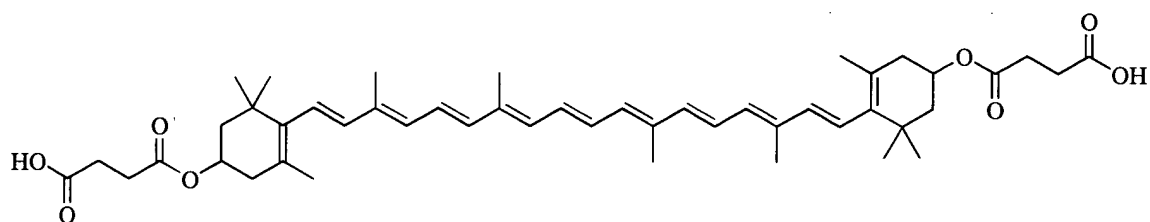
478. The method of claim 435, wherein the carotenoid derivative having the structure



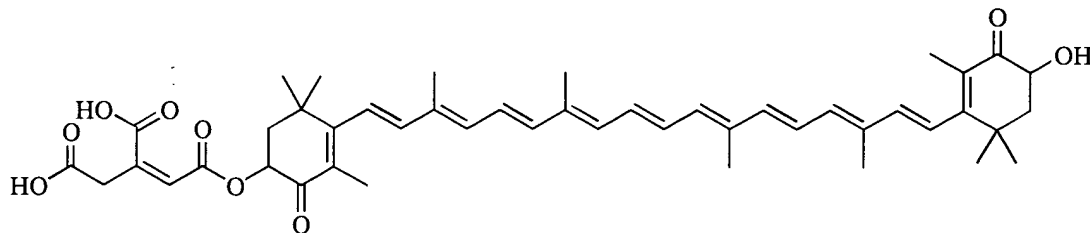
479. The method of claim 435, wherein the carotenoid derivative having the structure



5 480. The method of claim 435, wherein the carotenoid derivative having the structure

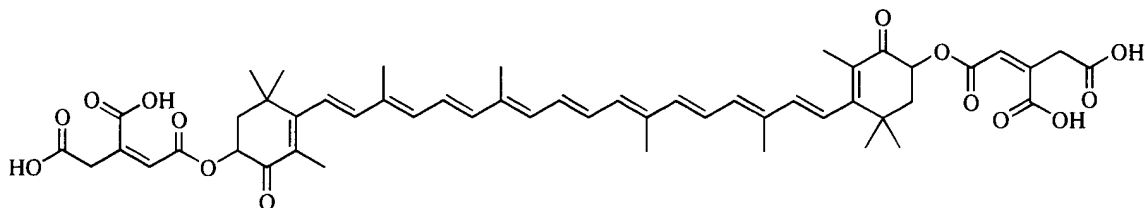


481. The method of claim 435, wherein the carotenoid derivative having the structure

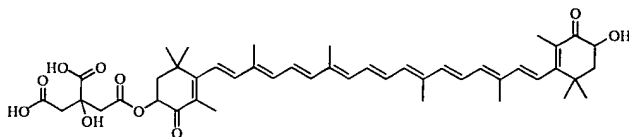


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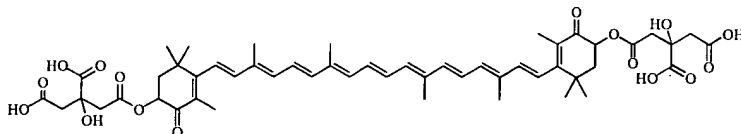
482. The method of claim 435, wherein the carotenoid derivative having the structure



15 483. The method of claim 435, wherein the carotenoid derivative having the structure

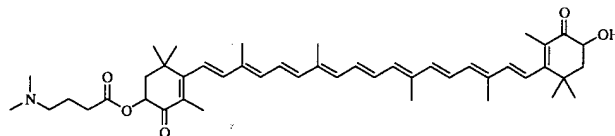


484. The method of claim 435, wherein the carotenoid derivative having the structure

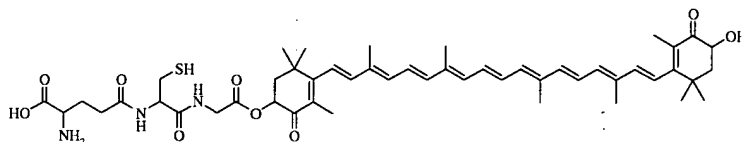


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485. The method of claim 435, wherein the carotenoid derivative having the structure

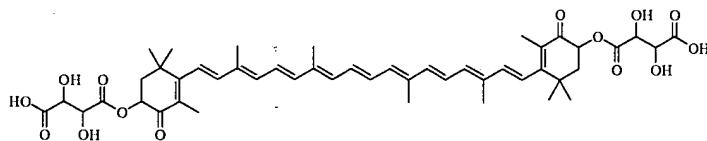


486. The method of claim 435, wherein the carotenoid derivative having the structure

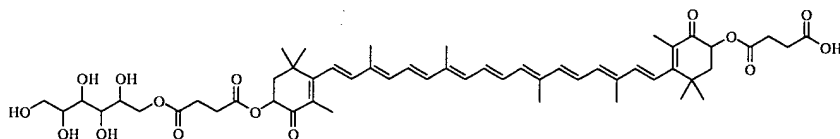


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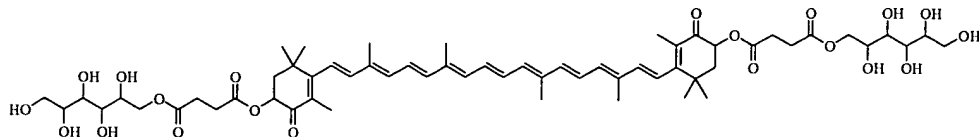
487. The method of claim 435, wherein the carotenoid derivative having the structure



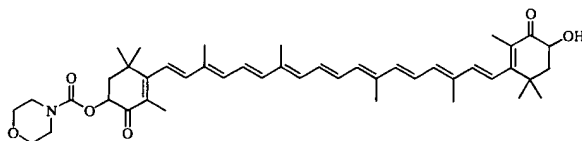
15 488. The method of claim 435, wherein the carotenoid derivative having the structure



489. The method of claim 435, wherein the carotenoid derivative having the structure

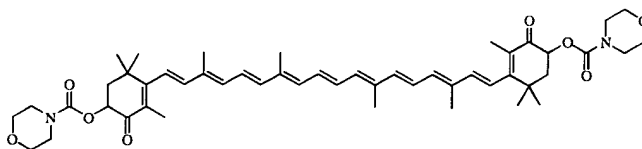


490. The method of claim 435, wherein the carotenoid derivative having the structure

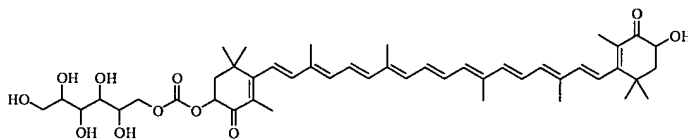


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491. The method of claim 435, wherein the carotenoid derivative having the structure

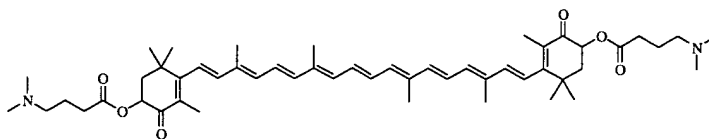


492. The method of claim 435, wherein the carotenoid derivative having the structure

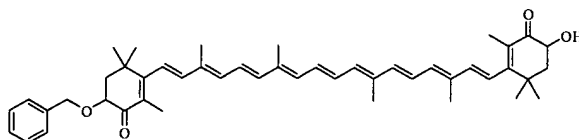


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493. The method of claim 435, wherein the carotenoid derivative having the structure

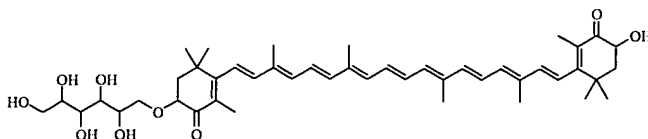


15 494. The method of claim 435, wherein the carotenoid derivative having the structure

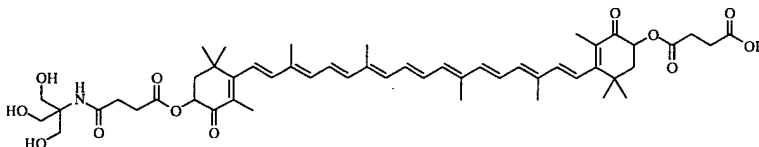


495. The method of claim 435, wherein the carotenoid derivative having the structure



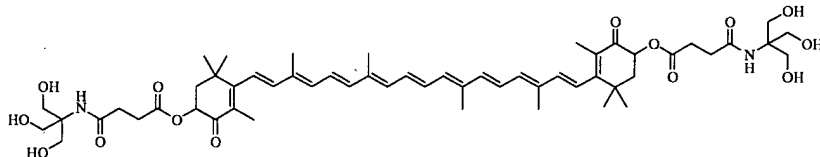


496. The method of claim 435, wherein the carotenoid derivative having the structure

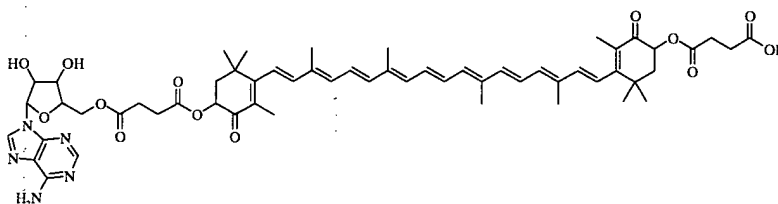


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497. The method of claim 435, wherein the carotenoid derivative having the structure

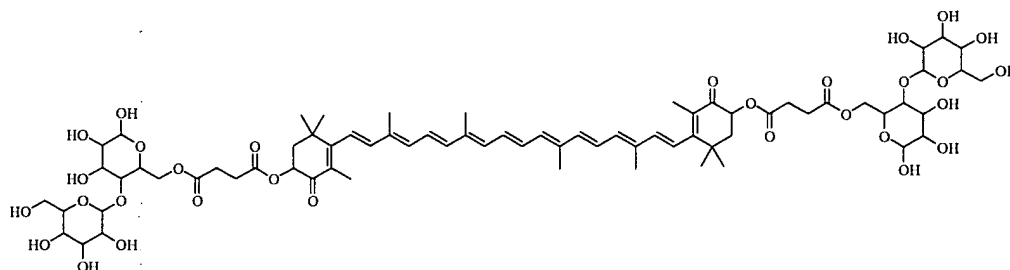


498. The method of claim 435, wherein the carotenoid derivative having the structure

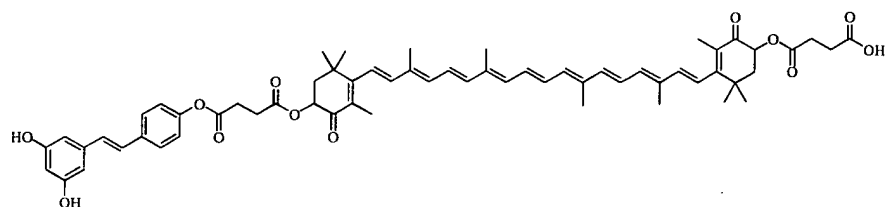


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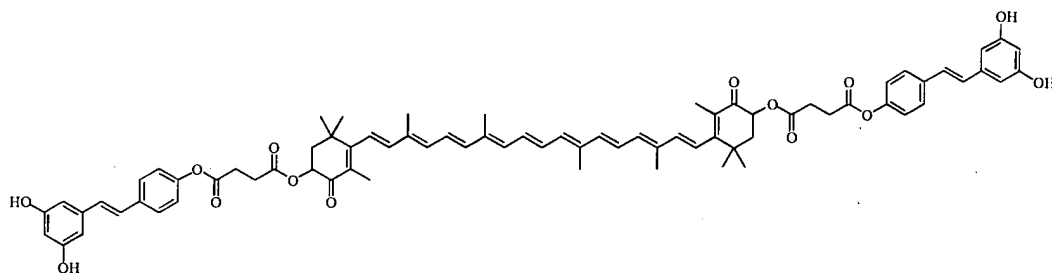
499. The method of claim 435, wherein the carotenoid derivative having the structure



500. The method of claim 435, wherein the carotenoid derivative having the structure



501. The method of claim 435, wherein the carotenoid derivative having the structure

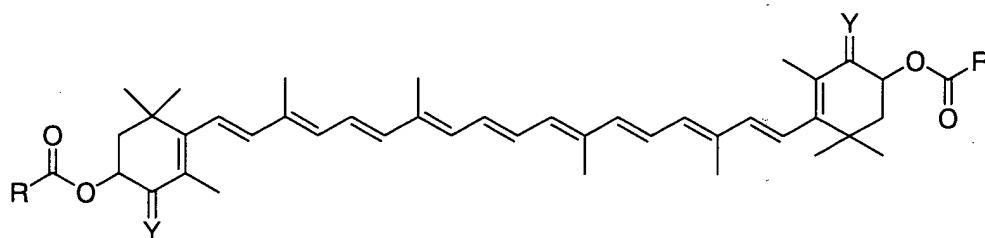


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502. A method of treating a liver disease with a chemical composition comprising a carotenoid derivative, comprising administering the carotenoid derivative to a subject;

10

wherein the carotenoid derivative has the structure



where each Y is independently O or H<sub>2</sub>;

15

where each R is independently OR<sup>1</sup> or R<sup>1</sup>;

where each R<sup>1</sup> is independently -alkyl-NR<sub>3</sub><sup>2+</sup>, -aromatic-NR<sub>3</sub><sup>2+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

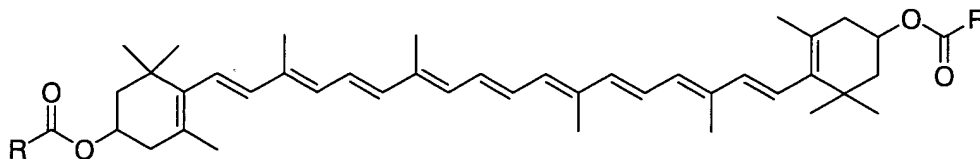
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where each R<sup>2</sup> is independently H, alkyl, or aryl.

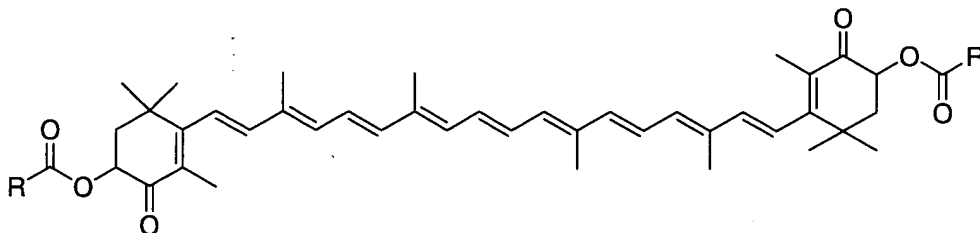
503. The method of claim 502, wherein the carotenoid derivative is at least partially  
5 water soluble.

504. The method of claim 502, wherein the liver disease is associated with Hepatitis C.

505. The method of claim 502, wherein Y is H<sub>2</sub>, the carotenoid derivative having the  
10 structure



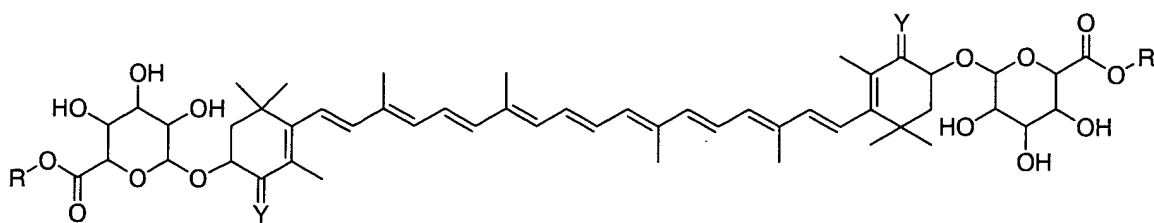
506. The method of claim 502, wherein Y is O, the carotenoid derivative having the  
structure



507. The method of claim 502, wherein the carotenoid derivative further comprises at  
least one chiral center.

508. A method of treating a liver disease with a chemical composition comprising a  
carotenoid derivative, comprising administering the carotenoid derivative to a  
subject;

wherein the carotenoid derivative has the structure



where each Y is independently O or H<sub>2</sub>;

5

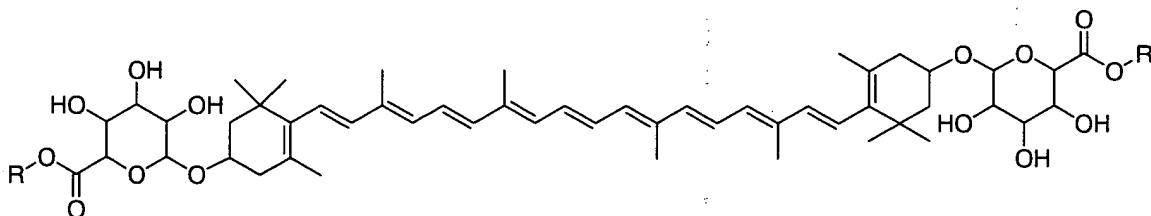
where each R is independently H, alkyl, or aryl.

509. The method of claim 508, wherein the carotenoid derivative is at least partially water soluble.

10

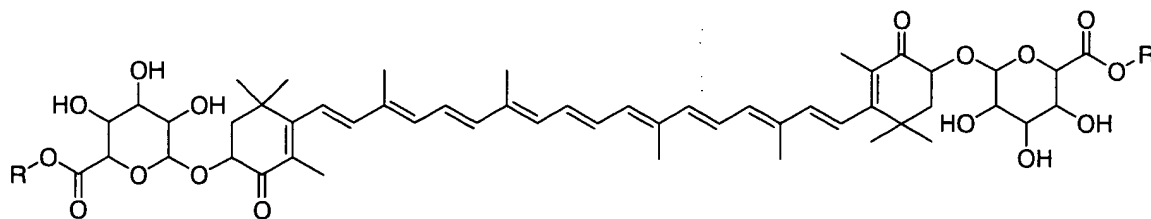
510. The method of claim 508, wherein the liver disease is associated with Hepatitis C.

511. The method of claim 508, wherein Y is H<sub>2</sub>, the carotenoid derivative having the structure



15

512. The method of claim 508, wherein Y is O, the carotenoid derivative having the structure

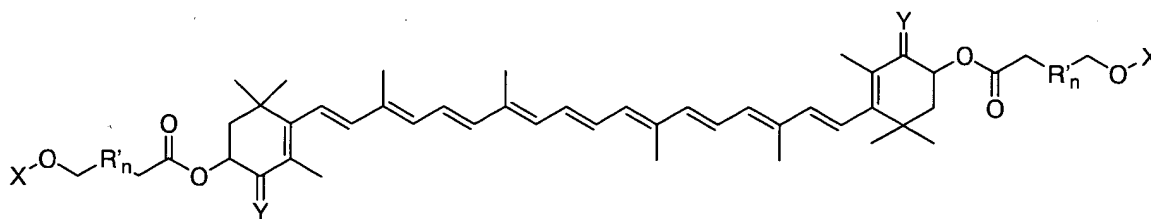


20

513. The method of claim 508, wherein the carotenoid derivative further comprises at least one chiral center.

514. A method of treating a liver disease with a chemical composition comprising a carotenoid derivative, comprising administering the carotenoid derivative to a subject;

wherein the carotenoid derivative has the structure

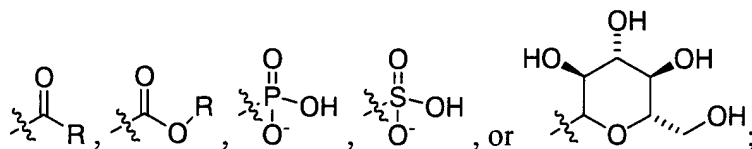


where each Y is independently O or H<sub>2</sub>;

where R' is CH<sub>2</sub>;

where n is 1 to 9;

where each X is independently

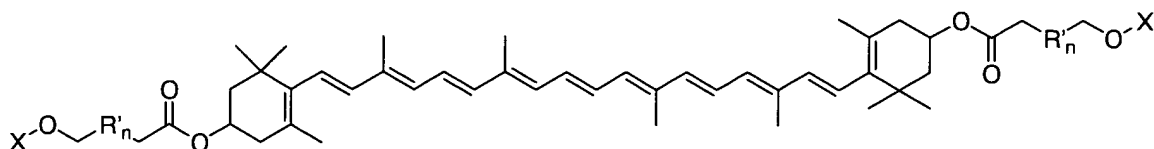


where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

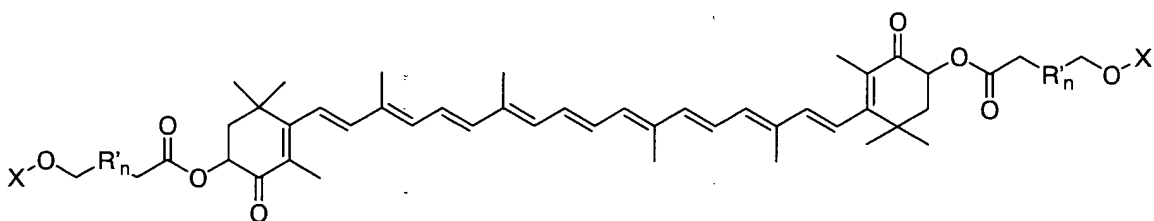
where each R<sup>1</sup> is independently H, alkyl, or aryl.

515. The method of claim 514, wherein the carotenoid derivative is at least partially water soluble.

516. The method of claim 514, wherein Y is H<sub>2</sub>, the carotenoid derivative having the structure



517. The method of claim 514, wherein Y is O, the carotenoid derivative having the structure

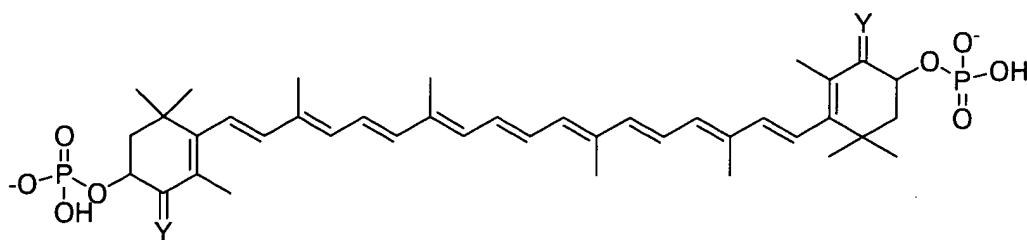


518. The method of claim 514, wherein the carotenoid derivative further comprises at least one chiral center.

519. The method of claim 514, wherein the liver disease is associated with Hepatitis C.

520. A method of treating a liver disease with a chemical composition comprising a carotenoid derivative, comprising administering the carotenoid derivative to a subject;

wherein the carotenoid derivative has the structure

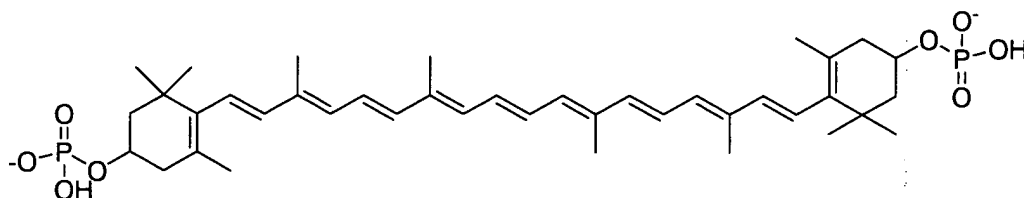


where each Y is independently O or H<sub>2</sub>.

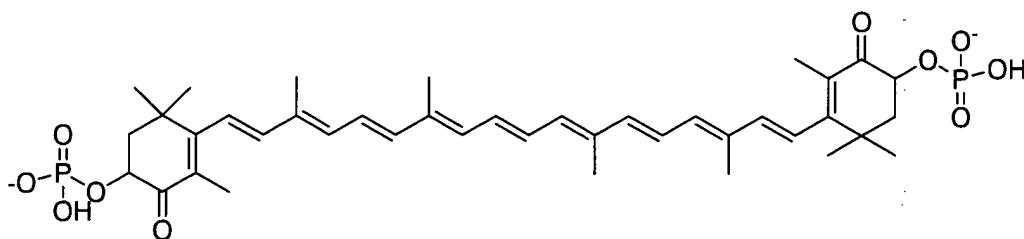
5 521. The method of claim 520, wherein the carotenoid derivative is at least partially water soluble.

522. The method of claim 520, wherein the liver disease is associated with Hepatitis C.

10 523. The method of claim 520, wherein Y is H<sub>2</sub>, the carotenoid derivative having the structure



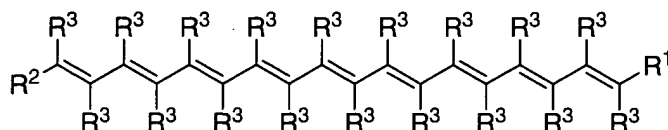
15 524. The method of claim 520, wherein Y is O, the carotenoid derivative having the structure



525. The method of claim 520, wherein the carotenoid derivative further comprises at least one chiral center.

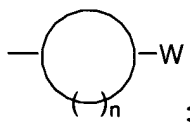
526. A method of treating arrhythmia with a chemical composition comprising a carotenoid derivative, comprising administering the carotenoid derivative to a subject;

wherein the carotenoid derivative has the structure



where each  $R^3$  is independently hydrogen or methyl;

where  $R^1$  and  $R^2$  are independently H, an acyclic alkene comprising at least one substituent, or a cyclic ring comprising at least one substituent, wherein the cyclic ring having general structure:



where n is 4 to 10 carbon atoms; and

where W is the substituent.

527. The method of claim 526, wherein each of the substituents  $-W$  independently comprises  $-XR$ , wherein each X independently comprises O, N, or S.

528. The method of claim 526, wherein each of the substituents  $-W$  independently comprises amino acids, esters, carbamates, amides, carbonates, alcohol, phosphates, or sulfonates.

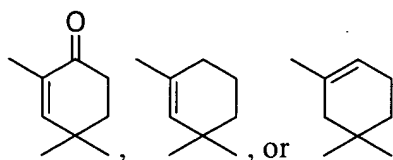
529. The method of claim 526, wherein the carotenoid derivative is at least partially water soluble.



530. The method of claim 526, wherein the substituent is at least partially hydrophilic.
531. The method of claim 526, further comprising increasing *connexin 43* expression.
- 5  
532. The method of claim 526, further comprising increasing intercellular gap  
junctional communication.
533. The method of claim 526, wherein the subject is a mammal.
- 10  
534. The method of claim 526, wherein the subject is human.
535. The method of claim 526, wherein administering the carotenoid derivative to a  
subject comprises administering the carotenoid derivative to a subject  
15 parenterally.
536. The method of claim 526, wherein administering the carotenoid derivative to a  
subject comprises administering the carotenoid derivative to a subject parenterally  
at a dose of about 5 to 300 mg per day.
- 20  
537. The method of claim 526, wherein administering the carotenoid derivative to a  
subject comprises administering the carotenoid derivative to a subject parenterally  
at a dose of about 0.25 mg to 1.0 g per day.
- 25  
538. The method of claim 526, wherein administering the carotenoid derivative to a  
subject comprises intracoronary administration of the carotenoid derivative to a  
subject.
539. The method of claim 526, wherein administering the carotenoid derivative to a  
30 subject comprises intracoronary administration of the carotenoid derivative to a  
subject at a dose of about 5 to 300 mg per day.

540. The method of claim 526, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 0.25 mg to 1.0 g per day.
- 5
541. The method of claim 526, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject subcutaneously.
- 10 542. The method of claim 526, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally.
543. The method of claim 526, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a
- 15 dose of about 5 to 100 mg per day.
544. The method of claim 526, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a
- 20 dose of about 0.25 mg to 1.0 g per day.
545. The method of claim 526, wherein administering the carotenoid derivative to a subject comprises a dose in a range of about 0.25 mg to 1 g.
546. The method of claim 526, wherein administering the carotenoid derivative to a
- 25 subject comprises at least two different carotenoid derivatives.
547. The method of claim 526, wherein the cyclic ring further comprises at least one chiral center.
- 30 548. The method of claim 526, wherein the cyclic ring further comprises at least one degree of unsaturation.

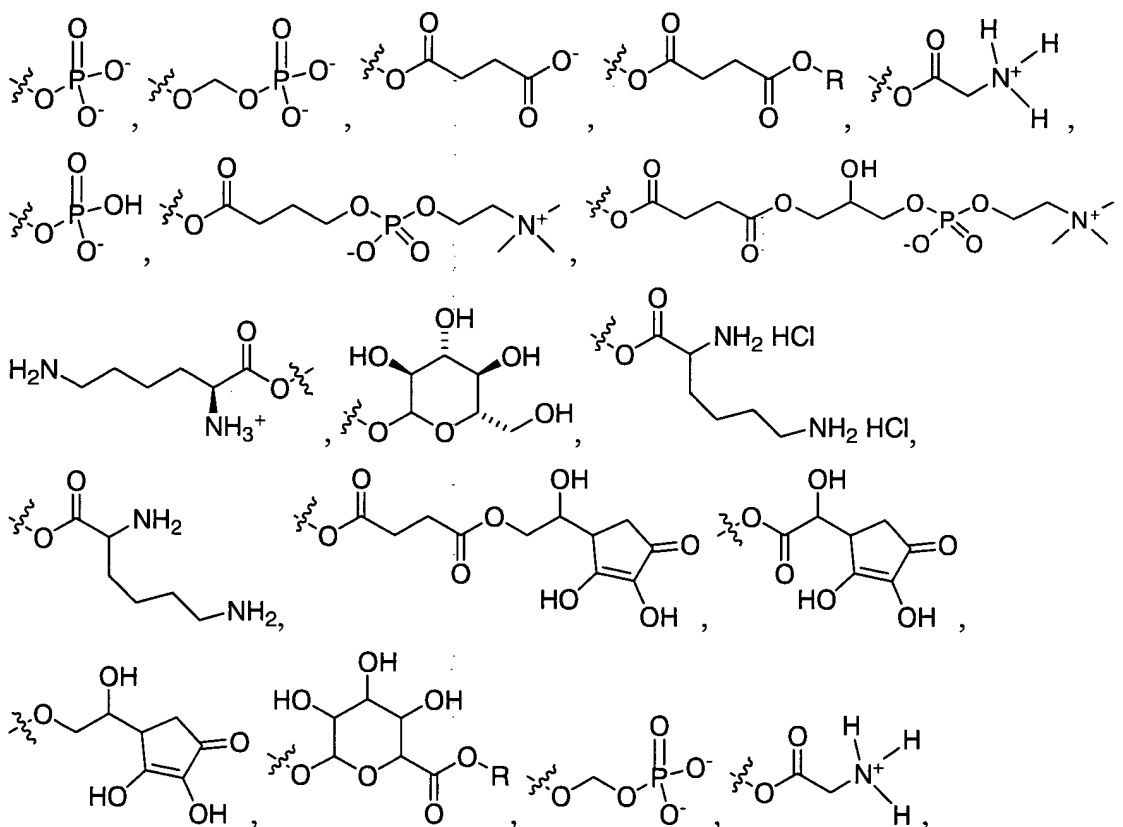
549. The method of claim 526, wherein each cyclic ring is independently



5

550. The method of claim 526, wherein the substituent is a carboxylic acid, an ester, an alkanol, an amine, a phosphate, a succinate, a glycinate, an ether, a glucoside, a sugar, or a carboxylate salt.

10 551. The method of claim 526, wherein each substituent is independently

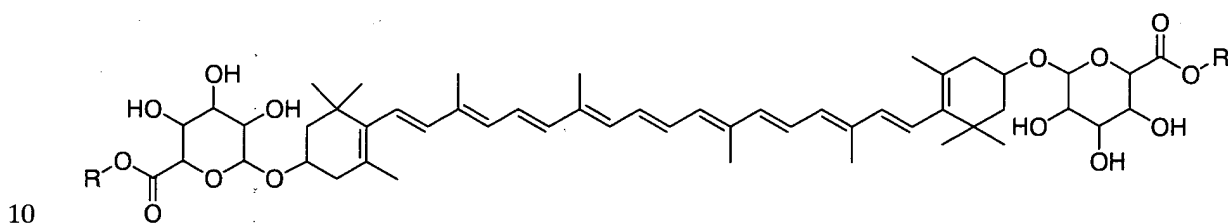




552. The method of claim 526, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid.

553. The method of claim 526, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid, and wherein the naturally occurring carotenoid is lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or canthaxanthin.

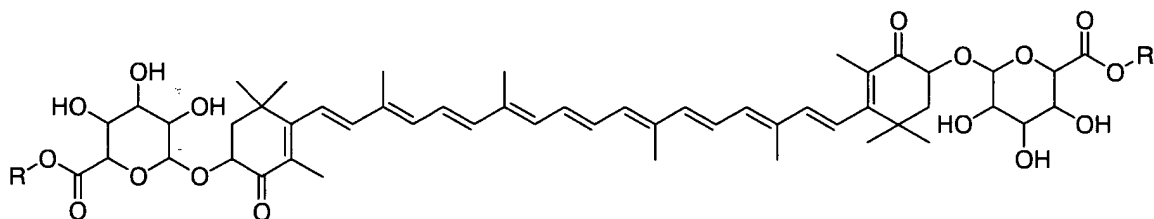
554. The method of claim 526, wherein the carotenoid derivative having the structure



where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

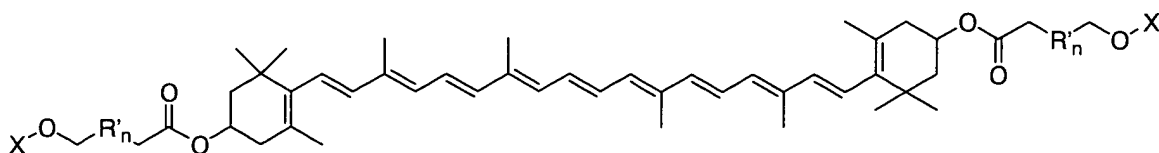
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555. The method of claim 526, wherein the carotenoid derivative having the structure



20 where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

556. The method of claim 526, wherein the carotenoid derivative having the structure

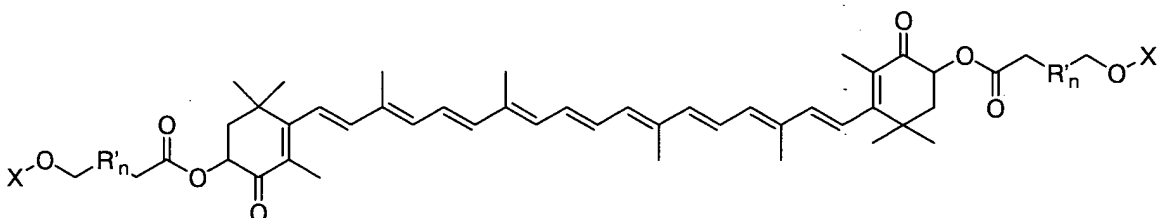


where each X is independently  $-\text{alkyl}-\text{NR}^1_3^+$ ,  $-\text{aromatic}-\text{NR}^1_3^+$ ,  $-\text{alkyl}-\text{CO}_2^-$ ,  $-\text{aromatic}-\text{CO}_2^-$ ,  $-\text{amino acid}-\text{NH}_3^+$ ,  $-\text{phosphorylated amino acid}-\text{NH}_3^+$ , polyethylene glycol, dextran,  
 5 H, alkyl, or aryl;

where each R' is independently  $-\text{alkyl}-\text{O}$ , alkyl, or aryl; and

where n is between about 0 and 12.

10 557. The method of claim 526, wherein the carotenoid derivative having the structure

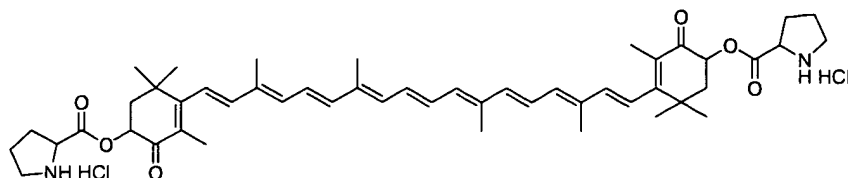


where each X is independently  $-\text{alkyl}-\text{NR}^1_3^+$ ,  $-\text{aromatic}-\text{NR}^1_3^+$ ,  $-\text{alkyl}-\text{CO}_2^-$ ,  $-\text{aromatic}-\text{CO}_2^-$ ,  $-\text{amino acid}-\text{NH}_3^+$ ,  $-\text{phosphorylated amino acid}-\text{NH}_3^+$ , polyethylene glycol, dextran,  
 15 H, alkyl, or aryl;

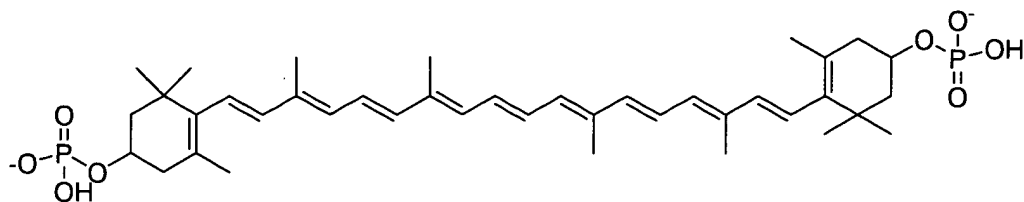
where each R' is independently  $-\text{alkyl}-\text{O}$ , alkyl, or aryl; and

20 where n is between about 0 and 12.

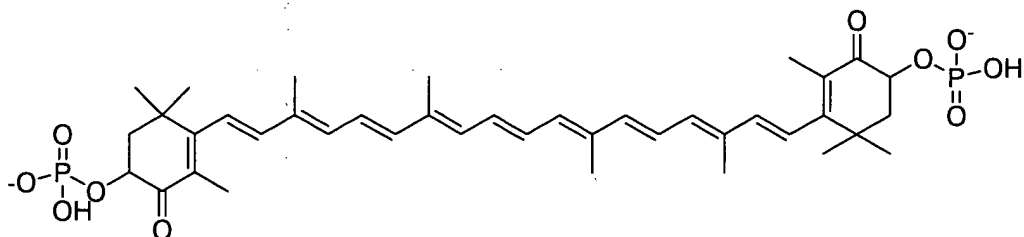
558. The method of claim 526, wherein the carotenoid derivative having the structure



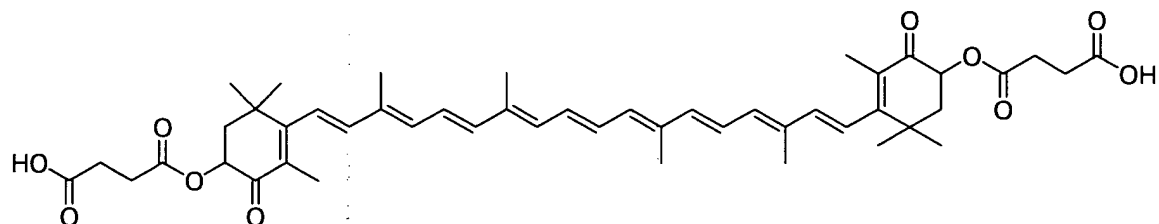
559. The method of claim 526, wherein the carotenoid derivative having the structure



560. The method of claim 526, wherein the carotenoid derivative having the structure

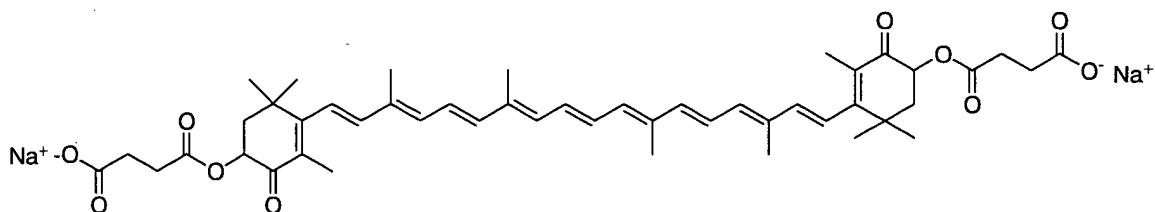


561. The method of claim 526, wherein the carotenoid derivative having the structure

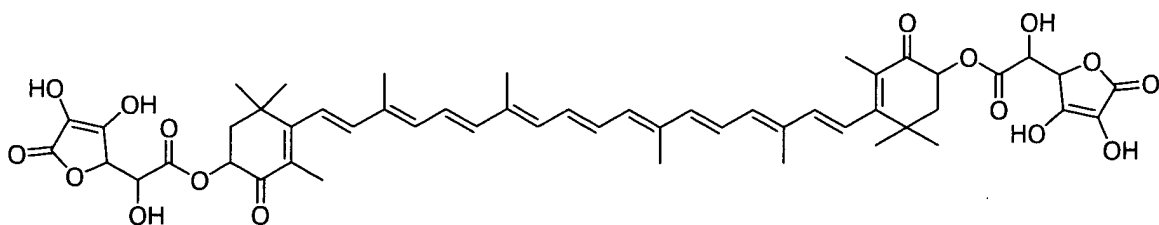


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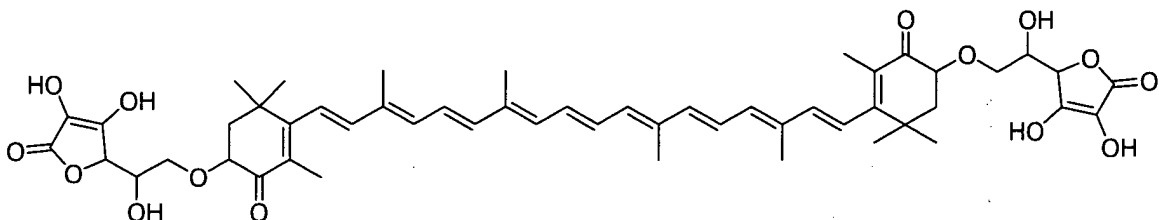
562. The method of claim 526, wherein the carotenoid derivative having the structure



563. The method of claim 526, wherein the carotenoid derivative having the structure

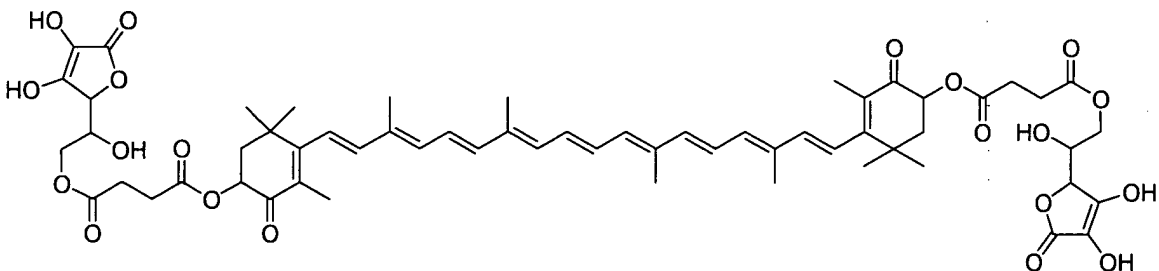


564. The method of claim 526, wherein the carotenoid derivative having the structure

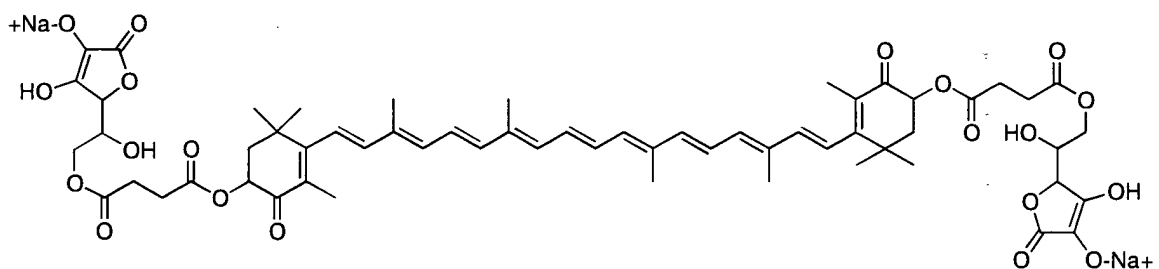


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565. The method of claim 526, wherein the carotenoid derivative having the structure



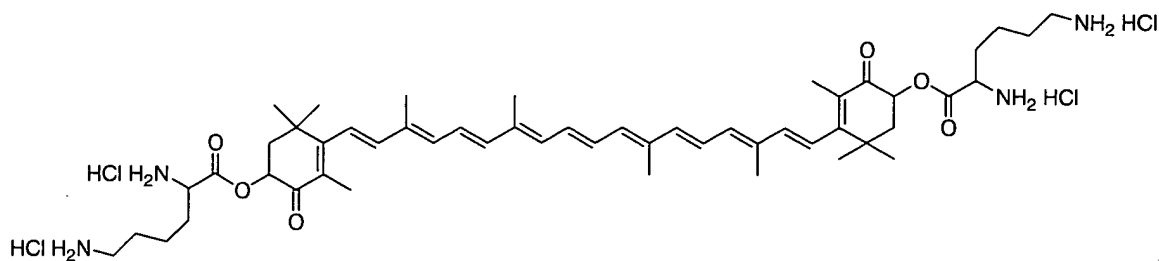
566. The method of claim 526, wherein the carotenoid derivative having the structure



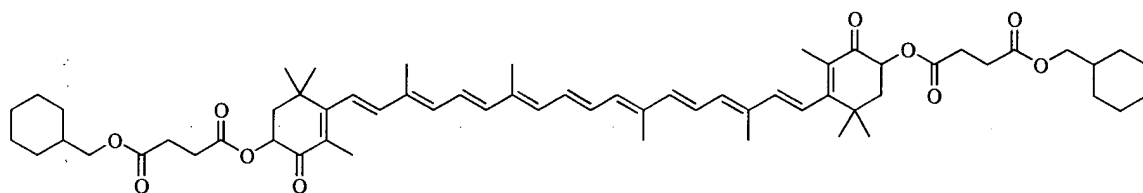
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567. The method of claim 526, wherein the carotenoid derivative having the structure



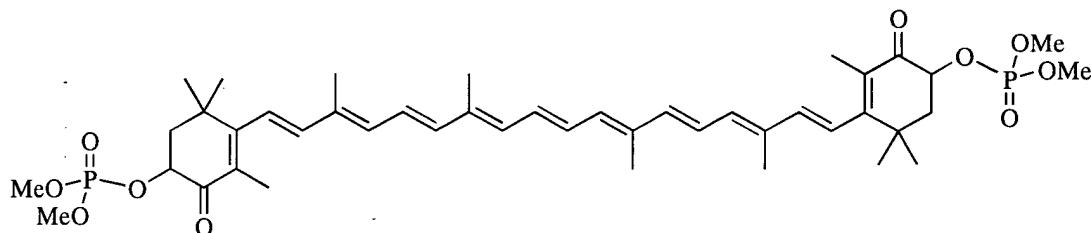


568. The method of claim 526, wherein the carotenoid derivative having the structure

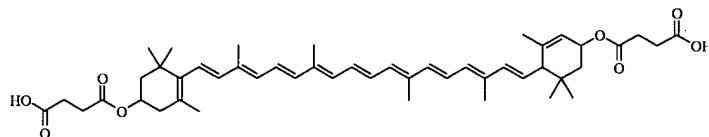


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569. The method of claim 526, wherein the carotenoid derivative having the structure

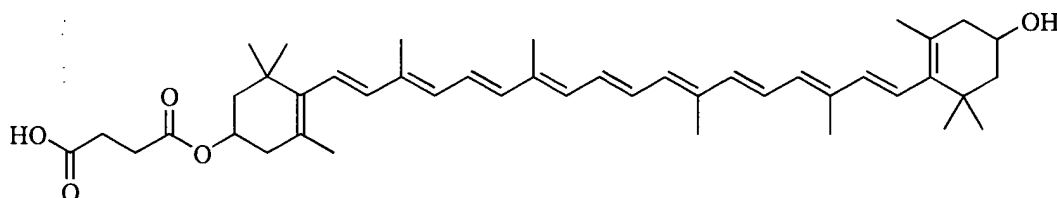


570. The method of claim 526, wherein the carotenoid derivative having the structure

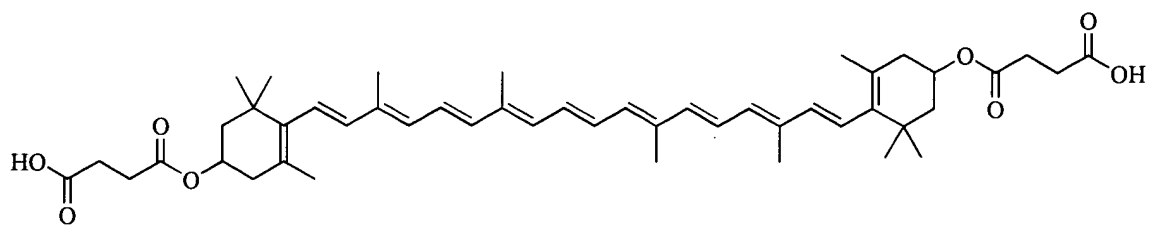


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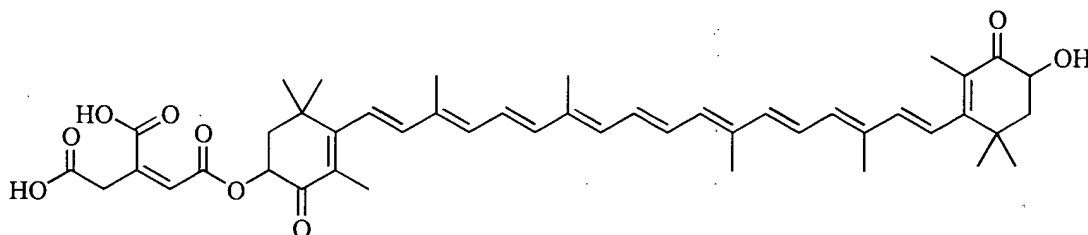
571. The method of claim 526, wherein the carotenoid derivative having the structure



15 572. The method of claim 526, wherein the carotenoid derivative having the structure

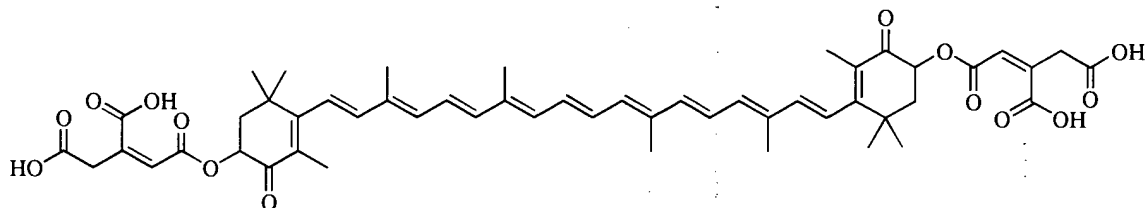


573. The method of claim 526, wherein the carotenoid derivative having the structure

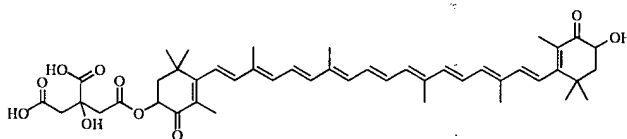


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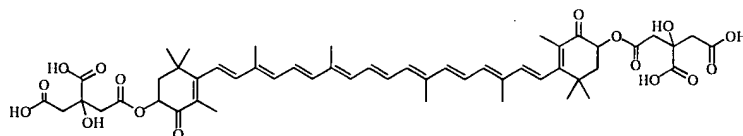
574. The method of claim 526, wherein the carotenoid derivative having the structure



10 575. The method of claim 526, wherein the carotenoid derivative having the structure

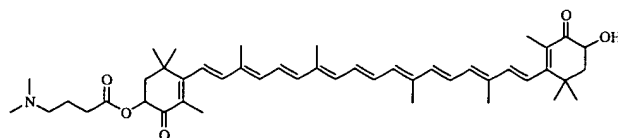


576. The method of claim 526, wherein the carotenoid derivative having the structure

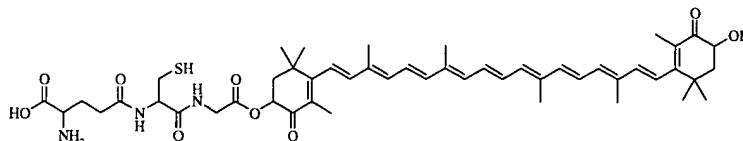


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577. The method of claim 526, wherein the carotenoid derivative having the structure

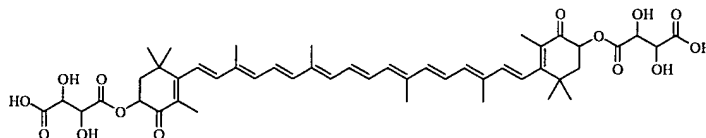


578. The method of claim 526, wherein the carotenoid derivative having the structure

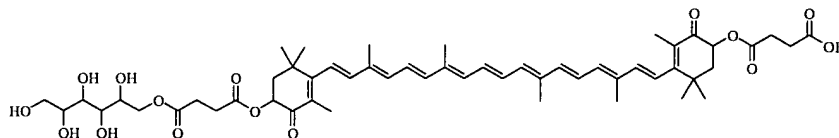


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579. The method of claim 526, wherein the carotenoid derivative having the structure

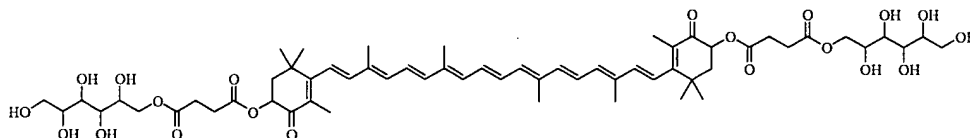


580. The method of claim 526, wherein the carotenoid derivative having the structure



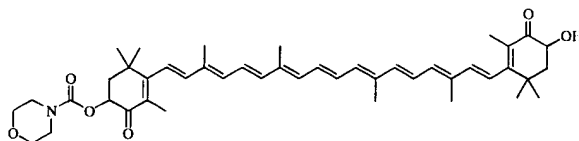
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581. The method of claim 526, wherein the carotenoid derivative having the structure

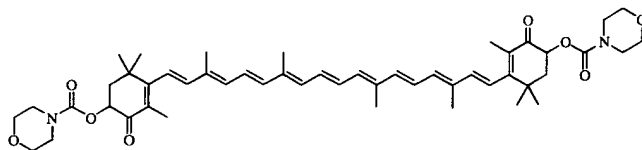


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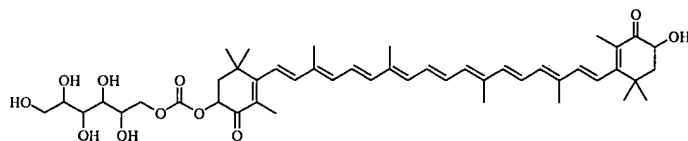
582. The method of claim 526, wherein the carotenoid derivative having the structure



583. The method of claim 526, wherein the carotenoid derivative having the structure

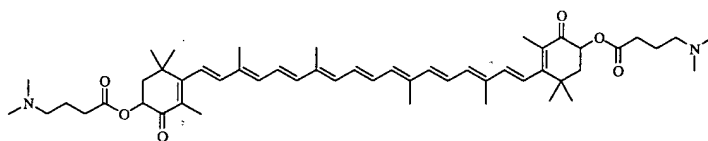


584. The method of claim 526, wherein the carotenoid derivative having the structure

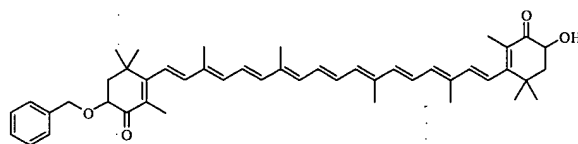


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585. The method of claim 526, wherein the carotenoid derivative having the structure

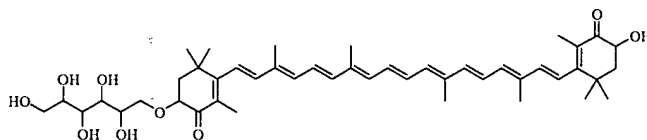


586. The method of claim 526, wherein the carotenoid derivative having the structure

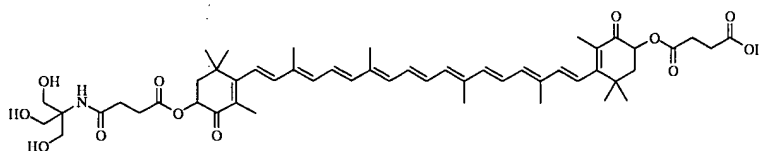


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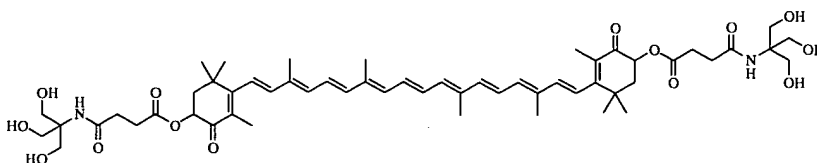
587. The method of claim 526, wherein the carotenoid derivative having the structure



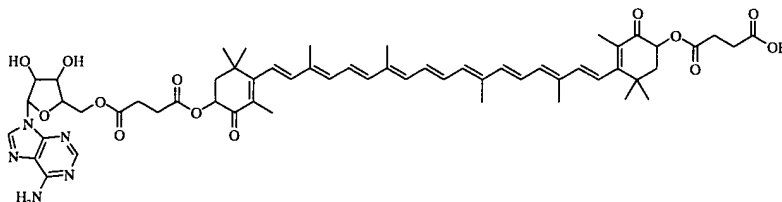
15 588. The method of claim 526, wherein the carotenoid derivative having the structure



589. The method of claim 526, wherein the carotenoid derivative having the structure

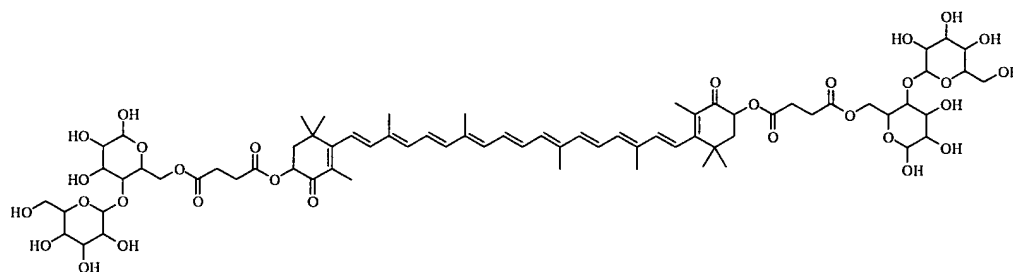


590. The method of claim 526, wherein the carotenoid derivative having the structure

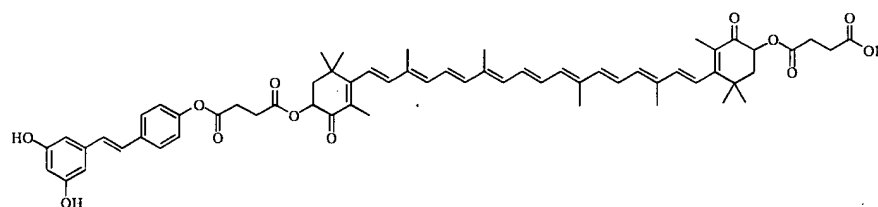


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591. The method of claim 526, wherein the carotenoid derivative having the structure

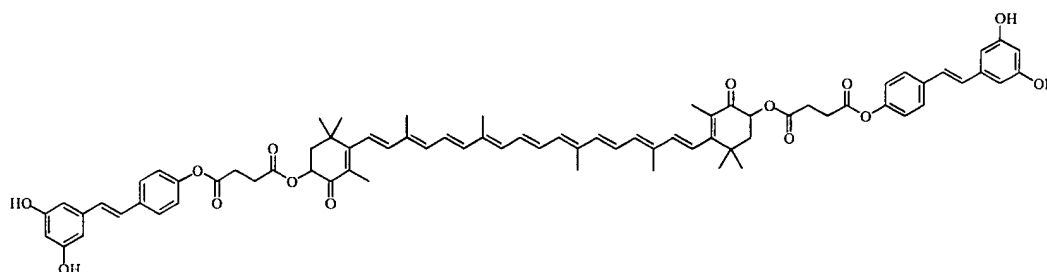


592. The method of claim 526, wherein the carotenoid derivative having the structure



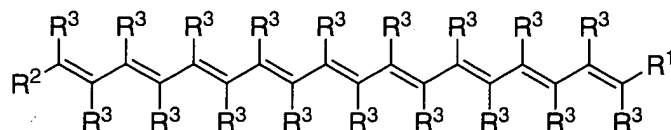
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593. The method of claim 526, wherein the carotenoid derivative having the structure



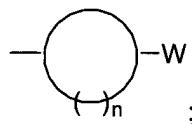
594. A method of treating cancerous and pre-cancerous cell(s) with a chemical composition comprising a carotenoid derivative, comprising administering the carotenoid derivative to a subject;

5 wherein the carotenoid derivative has the structure



where each R<sup>3</sup> is independently hydrogen or methyl;

10 where R<sup>1</sup> and R<sup>2</sup> are independently H, an acyclic alkene comprising at least one substituent, or a cyclic ring comprising at least one substituent, wherein the cyclic ring having general structure:



15 where n is 4 to 10 carbon atoms; and

where W is the substituent.

20 595. The method of claim 594, wherein each of the substituents -W independently comprises -XR, wherein each X independently comprises O, N, or S.

596. The method of claim 594, wherein each of the substituents -W independently comprises amino acids, esters, carbamates, amides, carbonates, alcohol,  
25 phosphates, or sulfonates.

597. The method of claim 594, wherein the carotenoid derivative is at least partially water soluble.

598. The method of claim 594, wherein the substituent is at least partially hydrophilic.
599. The method of claim 594, further comprising reducing the proliferation rate of  
5 cancerous and pre-cancerous cell(s).
600. The method of claim 594, wherein cancerous cell(s) comprise carcinogen-initiated cell(s).
- 10 601. The method of claim 594, further comprising increasing *connexin 43* expression.
602. The method of claim 594, further comprising increasing intercellular gap junctional communication.
- 15 603. The method of claim 594, wherein the subject is a mammal.
604. The method of claim 594, wherein the subject is human.
605. The method of claim 594, wherein administering the carotenoid derivative to a  
20 subject comprises administering the carotenoid derivative to a subject parenterally.
606. The method of claim 594, wherein administering the carotenoid derivative to a  
25 subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 5 to 300 mg per day.
607. The method of claim 594, wherein administering the carotenoid derivative to a  
30 subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 0.25 mg to 1.0 g per day.

608. The method of claim 594, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject.
- 5 609. The method of claim 594, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 5 to 300 mg per day.
- 10 610. The method of claim 594, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 0.25 mg to 1.0 g per day.
- 15 611. The method of claim 594, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject subcutaneously.
612. The method of claim 594, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally.
- 20 613. The method of claim 594, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 5 to 100 mg per day.
- 25 614. The method of claim 594, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 0.25 mg to 1.0 g per day.
- 30 615. The method of claim 594, wherein administering the carotenoid derivative to a subject comprises a dose in a range of about 0.25 mg to 1 g.

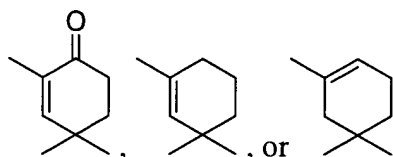


616. The method of claim 594, wherein administering the carotenoid derivative to a subject comprises at least two different carotenoid derivatives.

617. The method of claim 594, wherein the cyclic ring further comprises at least one chiral center.

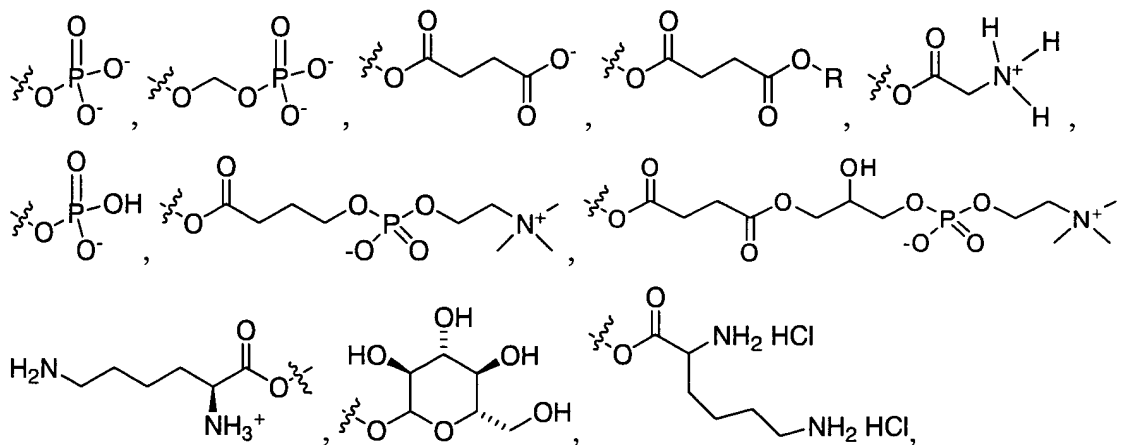
618. The method of claim 594, wherein the cyclic ring further comprises at least one degree of unsaturation.

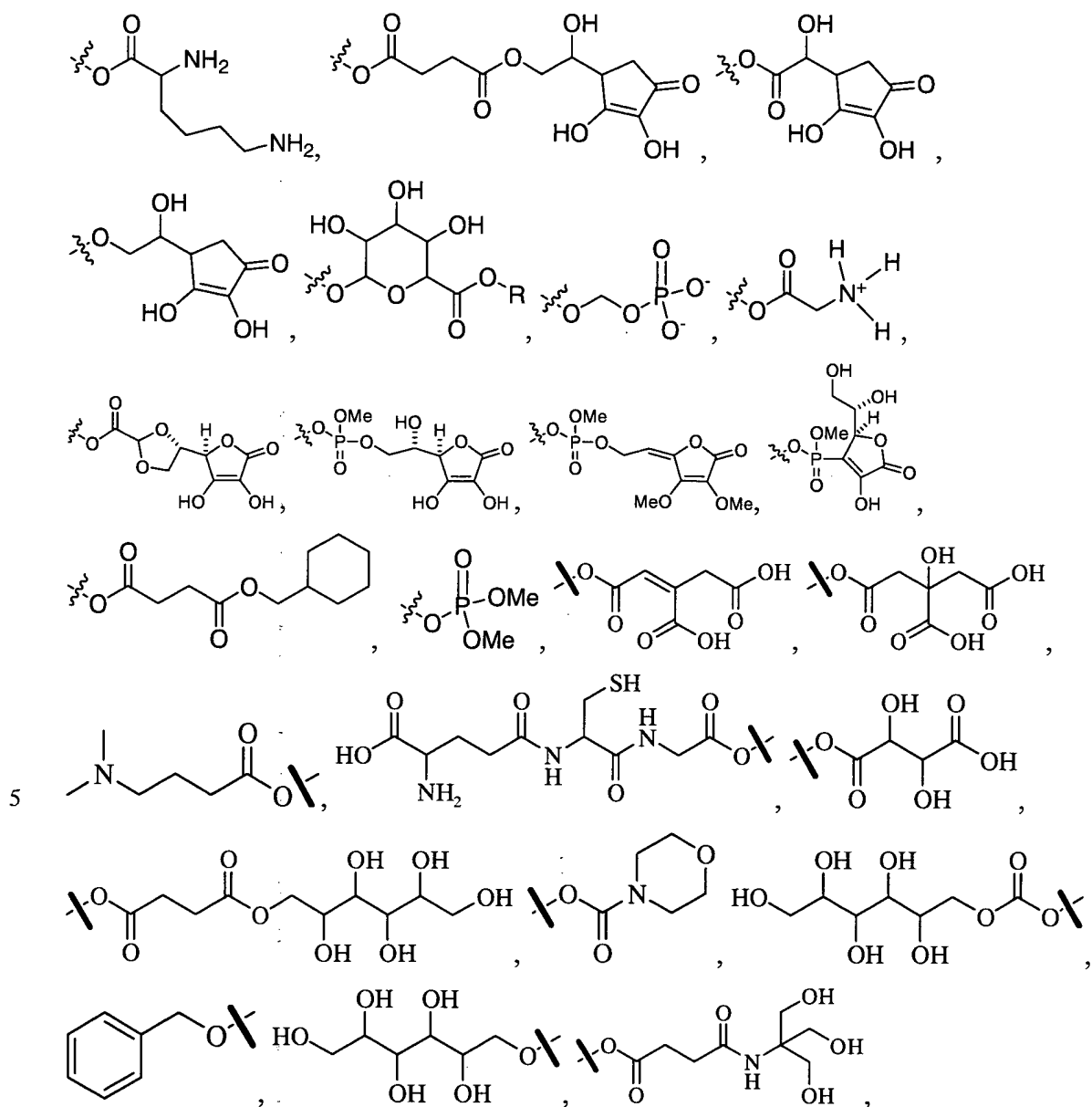
619. The method of claim 594, wherein each cyclic ring is independently

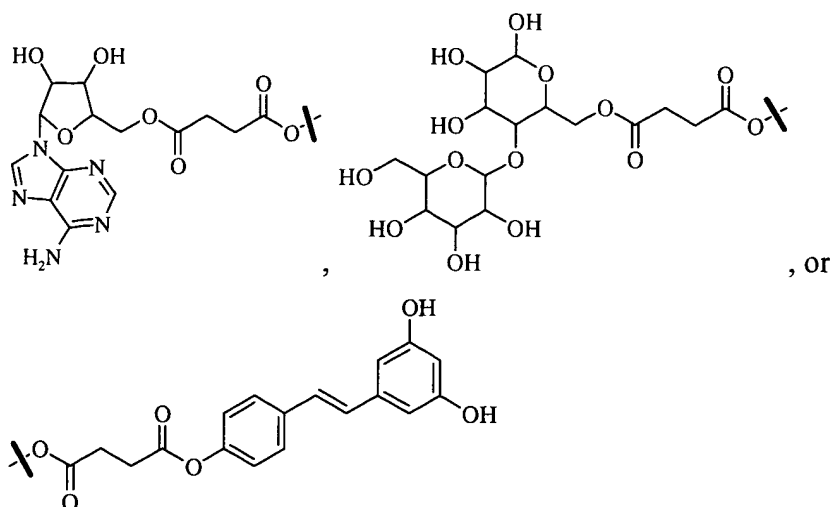


620. The method of claim 594, wherein the substituent is a carboxylic acid, an ester, an alkanol, an amine, a phosphate, a succinate, a glycinate, an ether, a glucoside, a sugar, or a carboxylate salt.

621. The method of claim 594, wherein each substituent is independently





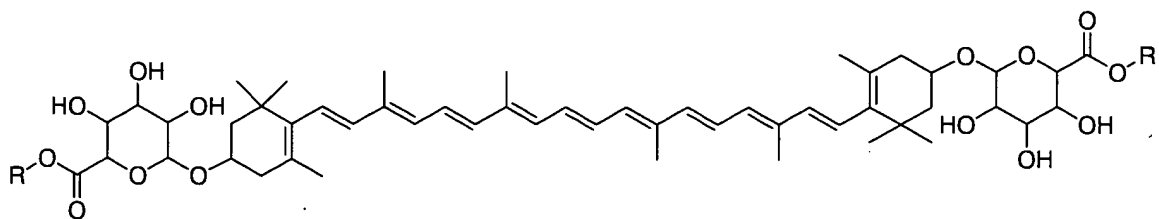


where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

622. The method of claim 594, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid.

623. The method of claim 594, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid, and wherein the naturally occurring carotenoid is lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or canthaxanthin.

624. The method of claim 594, wherein the carotenoid derivative having the structure

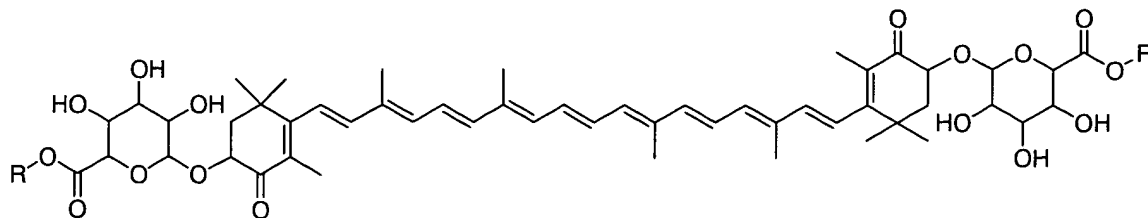


where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

Atty. Dkt. No.: 5777-00201

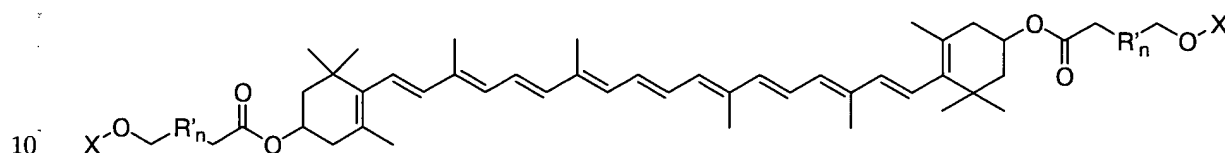
Meyertons, Hood, Kivlin,  
Kowert & Goetzel, P.C.

625. The method of claim 594, wherein the carotenoid derivative having the structure



5 where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

626. The method of claim 594, wherein the carotenoid derivative having the structure

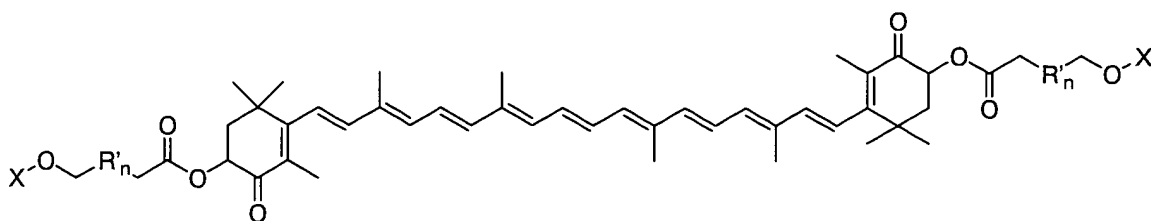


10 where each X is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

15 where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

20 627. The method of claim 594, wherein the carotenoid derivative having the structure

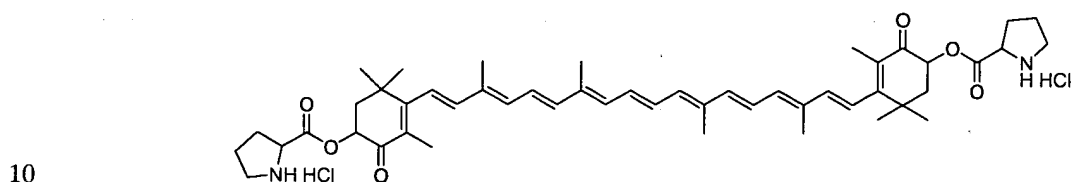


where each X is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

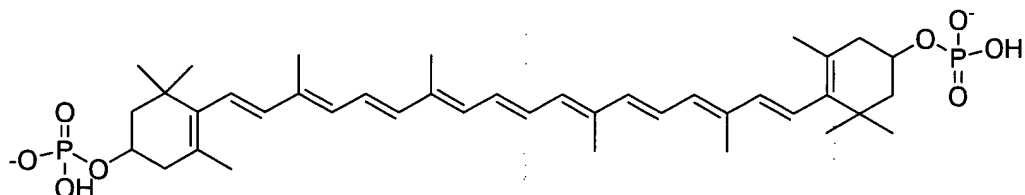
5 where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

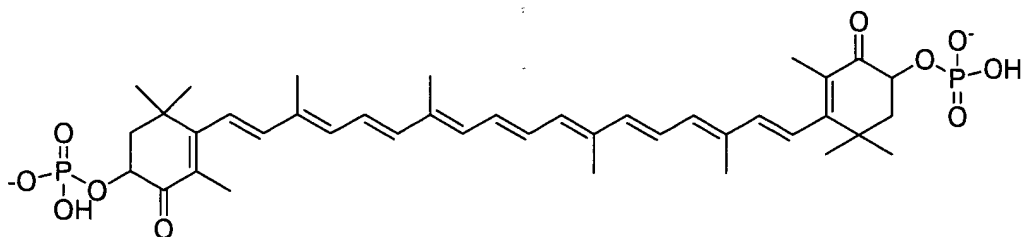
628. The method of claim 594, wherein the carotenoid derivative having the structure



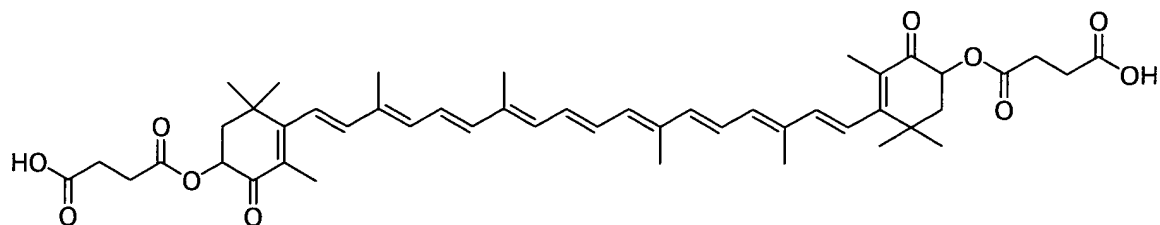
629. The method of claim 594, wherein the carotenoid derivative having the structure



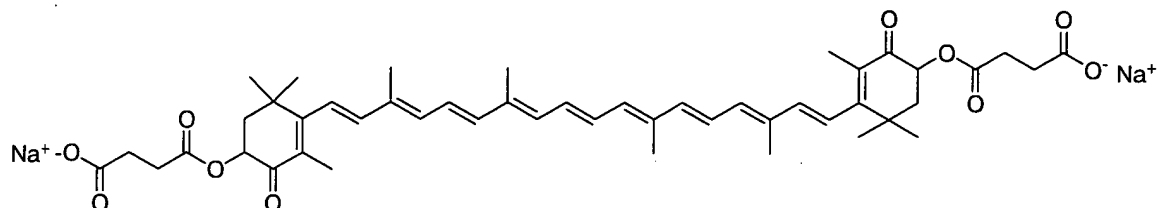
15 630. The method of claim 594, wherein the carotenoid derivative having the structure



631. The method of claim 594, wherein the carotenoid derivative having the structure

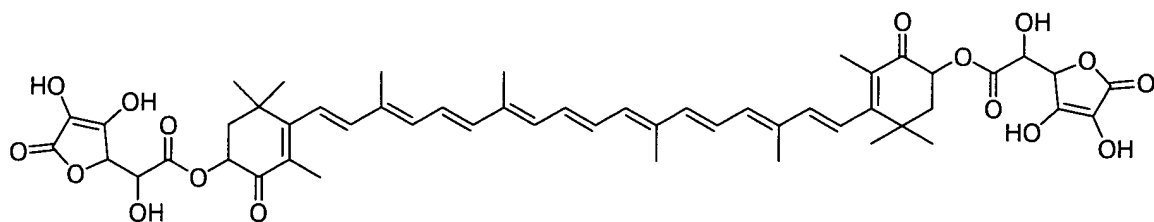


632. The method of claim 594, wherein the carotenoid derivative having the structure

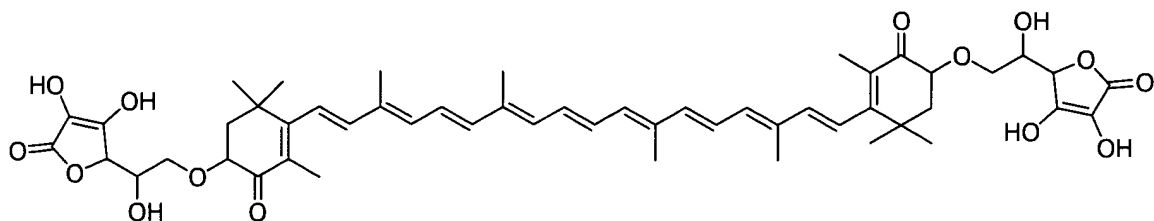


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633. The method of claim 594, wherein the carotenoid derivative having the structure

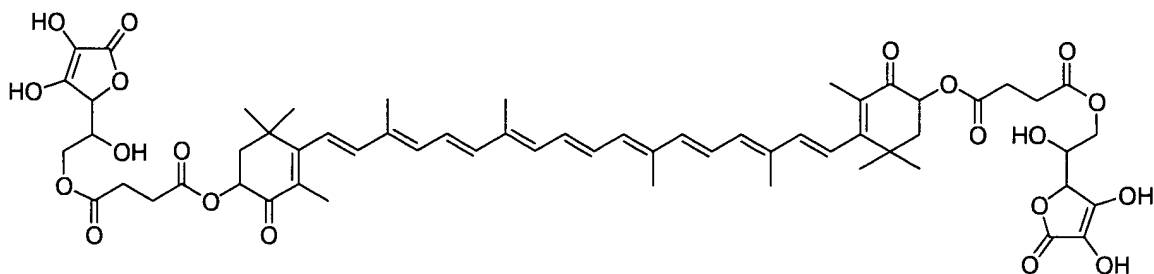


634. The method of claim 594, wherein the carotenoid derivative having the structure

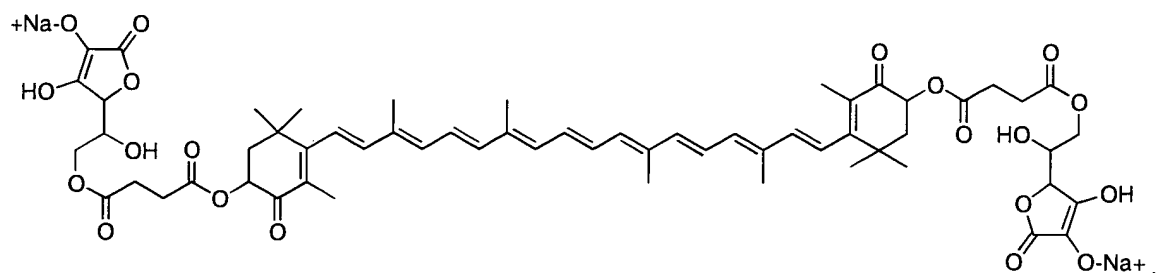


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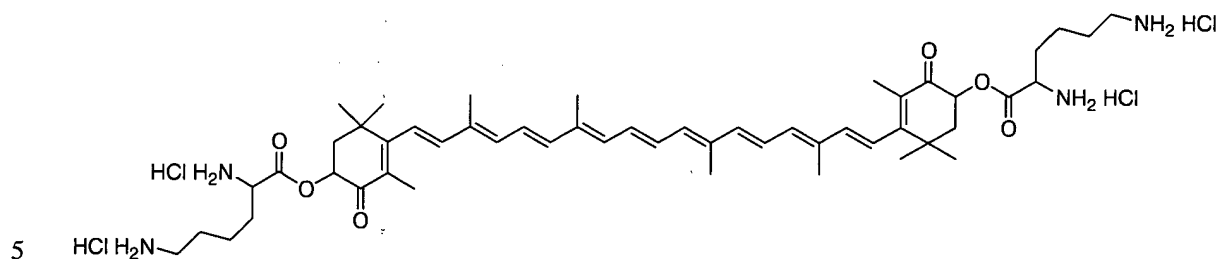
635. The method of claim 594, wherein the carotenoid derivative having the structure



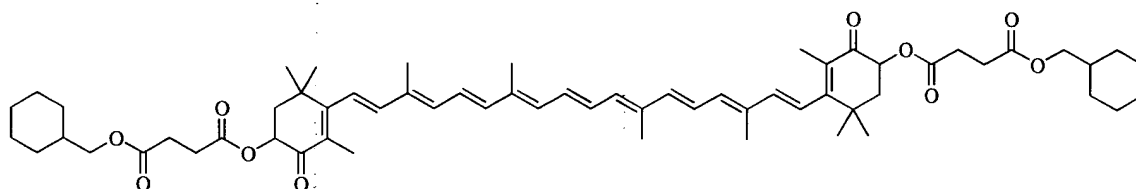
636. The method of claim 594, wherein the carotenoid derivative having the structure



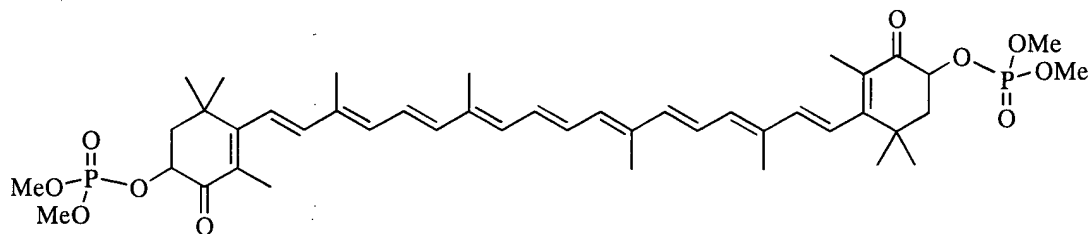
637. The method of claim 594, wherein the carotenoid derivative having the structure



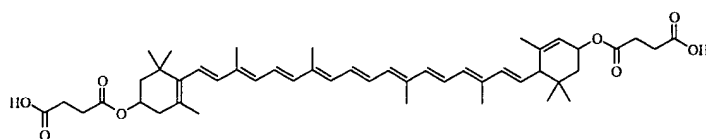
638. The method of claim 594, wherein the carotenoid derivative having the structure



639. The method of claim 594, wherein the carotenoid derivative having the structure



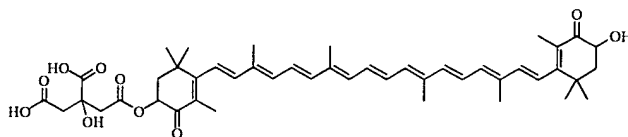
640. The method of claim 594, wherein the carotenoid derivative having the structure



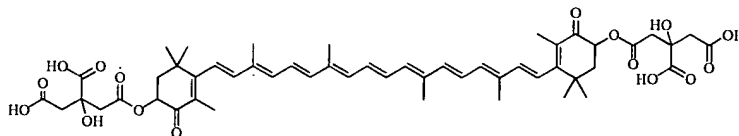
CC1=C(C)C(OC(=O)CCC(=O)O)C=C1/C=C/C(C)=C/C=C/C(C)=C/C=C/C(C)=C/C=C/C(C)=C/C=C/C(C)=C/C=C/C(C)=C/C=C/C1=C(C)C(O)C(C)(C)C1[illegible][illegible]OC(=O)CC(=O)OC(=O)C1=C(C)C(=O)C(C)=C1/C=C/C(C)=C/C=C/C(C)=C/C=C/C(C)=C/C=C/C(C)=C/C=C/C(C)=C/C=C/C1=C(C)C(=O)C(C)=C1OC(=O)C2=C(C)C(=O)C(C)=C2C(=O)O

645. The method of claim 594, wherein the carotenoid derivative having the structure



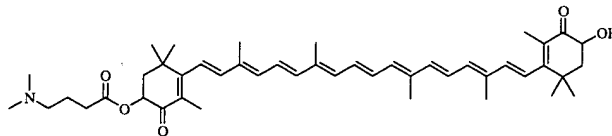


646. The method of claim 594, wherein the carotenoid derivative having the structure

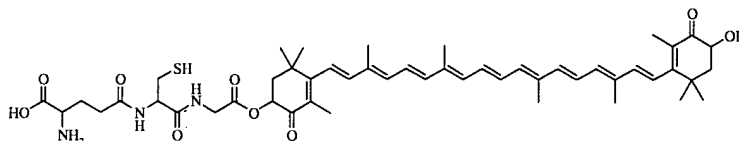


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647. The method of claim 594, wherein the carotenoid derivative having the structure

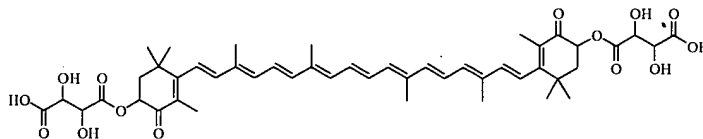


648. The method of claim 594, wherein the carotenoid derivative having the structure



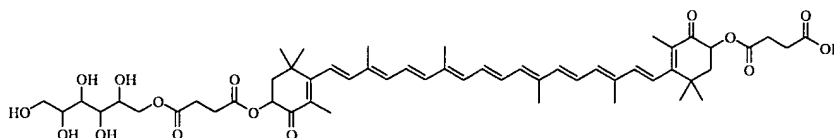
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649. The method of claim 594, wherein the carotenoid derivative having the structure

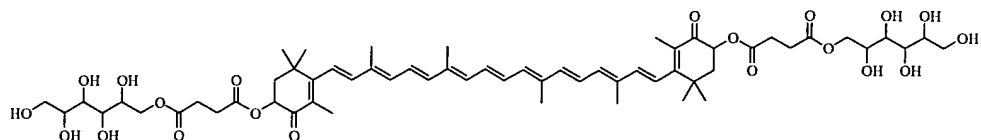


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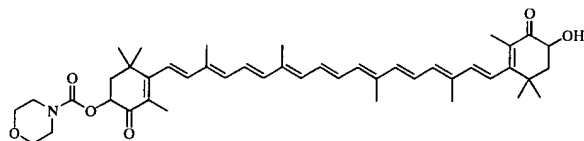
650. The method of claim 594, wherein the carotenoid derivative having the structure



651. The method of claim 594, wherein the carotenoid derivative having the structure

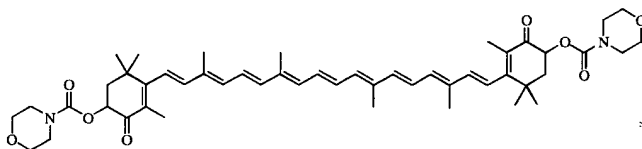


652. The method of claim 594, wherein the carotenoid derivative having the structure

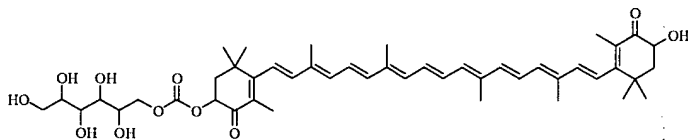


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653. The method of claim 594, wherein the carotenoid derivative having the structure

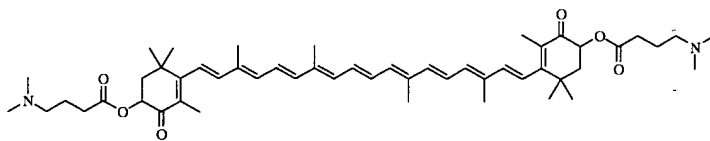


654. The method of claim 594, wherein the carotenoid derivative having the structure



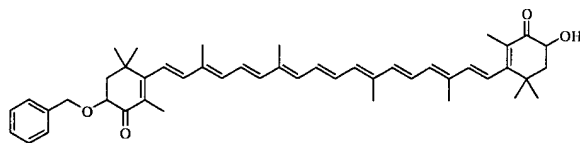
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655. The method of claim 594, wherein the carotenoid derivative having the structure

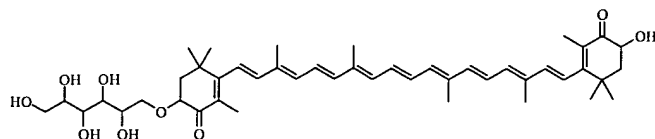


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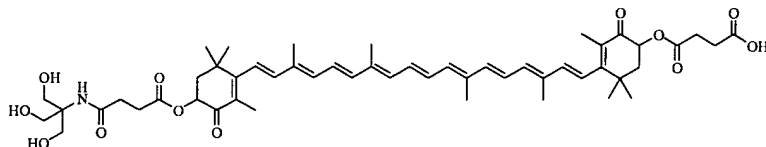
656. The method of claim 594, wherein the carotenoid derivative having the structure



657. The method of claim 594, wherein the carotenoid derivative having the structure

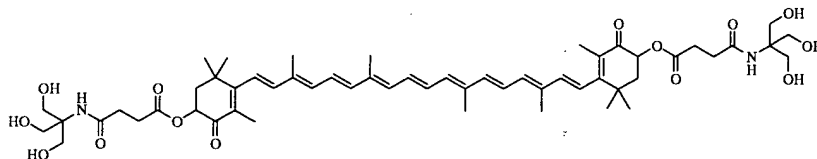


658. The method of claim 594, wherein the carotenoid derivative having the structure

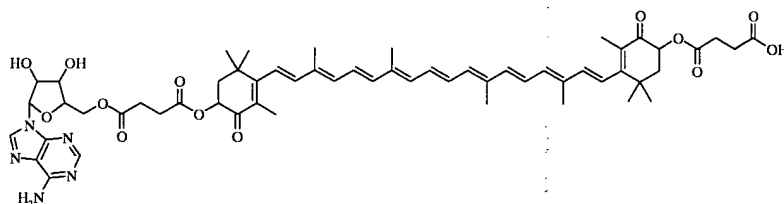


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659. The method of claim 594, wherein the carotenoid derivative having the structure

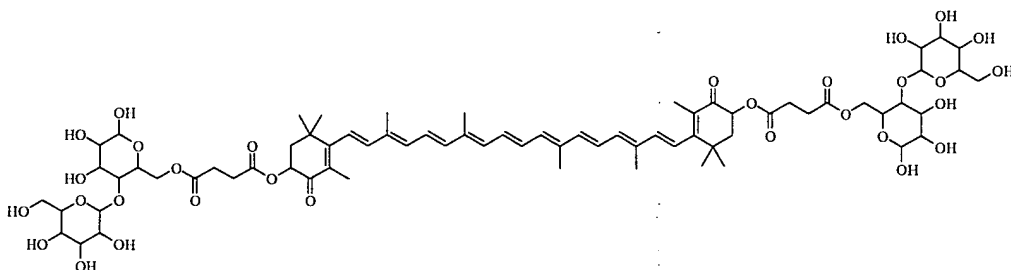


660. The method of claim 594, wherein the carotenoid derivative having the structure

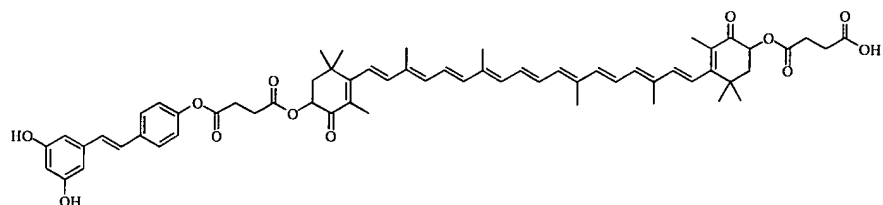


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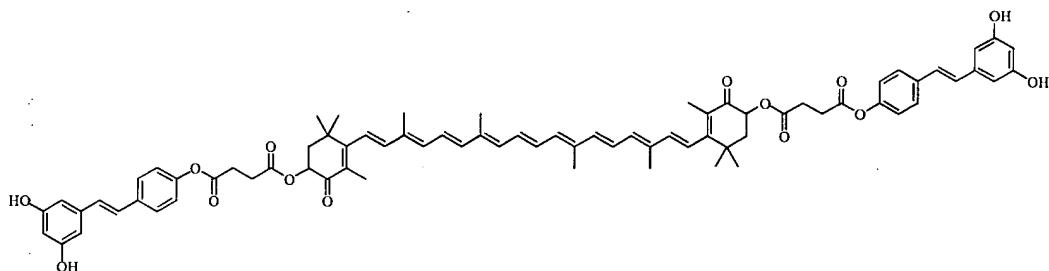
661. The method of claim 594, wherein the carotenoid derivative having the structure



15 662. The method of claim 594, wherein the carotenoid derivative having the structure



663. The method of claim 594, wherein the carotenoid derivative having the structure

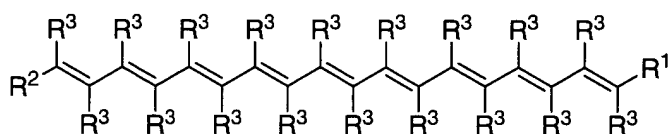


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664. A method of increasing *connexin 43* expression with a chemical composition comprising a carotenoid derivative, comprising administering the carotenoid derivative to a subject;

10

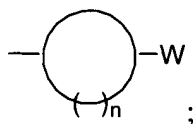
wherein the carotenoid derivative has the structure



where each  $R^3$  is independently hydrogen or methyl;

15

where  $R^1$  and  $R^2$  are independently H, an acyclic alkene comprising at least one substituent, or a cyclic ring comprising at least one substituent, wherein the cyclic ring having general structure:



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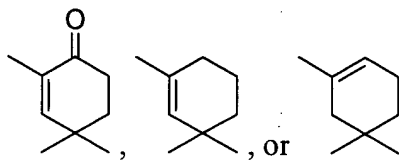
where n is 4 to 10 carbon atoms; and

where W is the substituent.

- 5     665.    The method of claim 664, wherein each of the substituents –W independently comprises –XR, wherein each X independently comprises O, N, or S.
666.    The method of claim 664, wherein each of the substituents –W independently comprises amino acids, esters, carbamates, amides, carbonates, alcohol,  
10     phosphates, or sulfonates.
667.    The method of claim 664, wherein the carotenoid derivative is at least partially water soluble.
- 15     668.    The method of claim 664, wherein the substituent is at least partially hydrophilic.
669.    The method of claim 664, further comprising reducing a proliferation rate of cancerous and pre-cancerous cell(s).
- 20     670.    The method of claim 664, further comprising reducing a proliferation rate of cancerous cell(s), wherein cancerous cell(s) comprise carcinogen-initiated cell(s).
671.    The method of claim 664, further comprising treating an ischemia-reperfusion injury.  
25
672.    The method of claim 664, further comprising increasing intercellular gap junctional communication.
673.    The method of claim 664, wherein the subject is a mammal.
- 30     674.    The method of claim 664, wherein the subject is human.

- 5
675. The method of claim 664, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally.
676. The method of claim 664, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 5 to 300 mg per day.
- 10 677. The method of claim 664, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 0.25 mg to 1.0 g per day.
- 15 678. The method of claim 664, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject.
- 20 679. The method of claim 664, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 5 to 300 mg per day.
- 25 680. The method of claim 664, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 0.25 mg to 1.0 g per day.
681. The method of claim 664, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject subcutaneously.
- 30 682. The method of claim 664, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally.

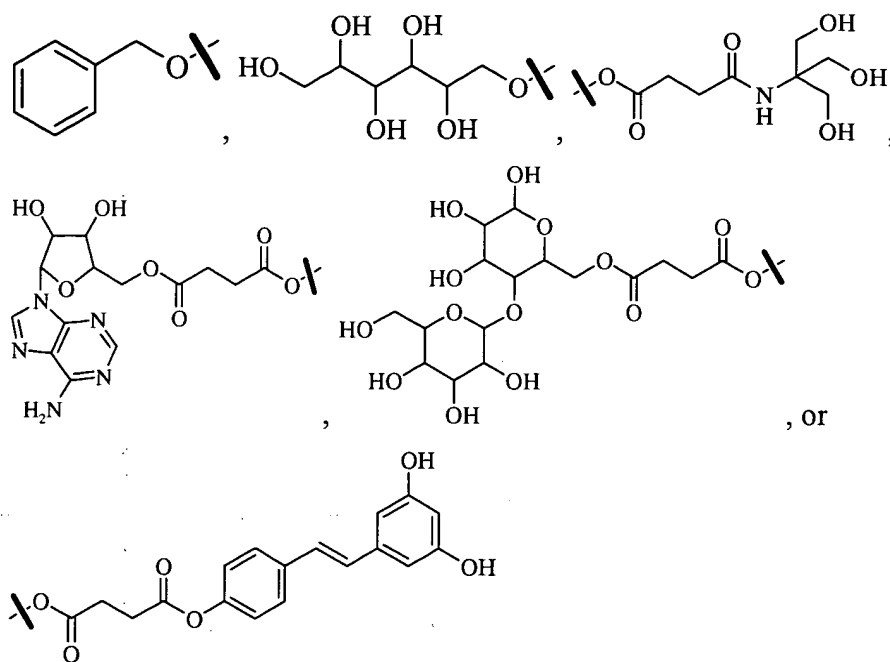
- 5
683. The method of claim 664, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 5 to 100 mg per day.
684. The method of claim 664, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 0.25 mg to 1.0 g per day.
- 10 685. The method of claim 664, wherein administering the carotenoid derivative to a subject comprises a dose in a range of about 0.25 mg to 1 g.
686. The method of claim 664, wherein administering the carotenoid derivative to a subject comprises at least two different carotenoid derivatives.
- 15 687. The method of claim 664, wherein the cyclic ring further comprises at least one chiral center.
688. The method of claim 664, wherein the cyclic ring further comprises at least one degree of unsaturation.
- 20 689. The method of claim 664, wherein each cyclic ring is independently



- 25 690. The method of claim 664, wherein the substituent is a carboxylic acid, an ester, an alkanol, an amine, a phosphate, a succinate, a glycinate, an ether, a glucoside, a sugar, or a carboxylate salt.

[illegible]



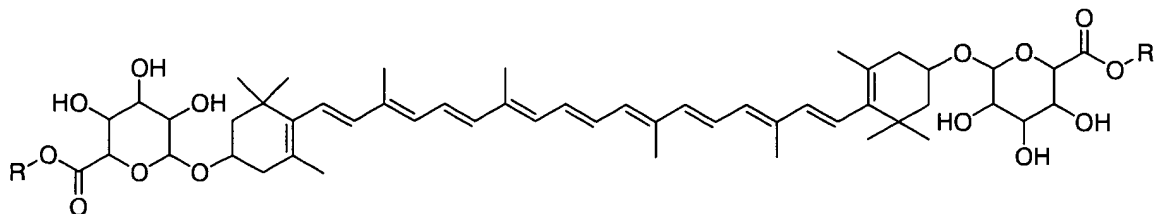


- 5 where each R is independently -alkyl-NR<sub>3</sub><sup>+</sup>, -aromatic-NR<sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

692. The method of claim 664, wherein the carotenoid derivative is a derivative of a  
10 naturally occurring carotenoid.

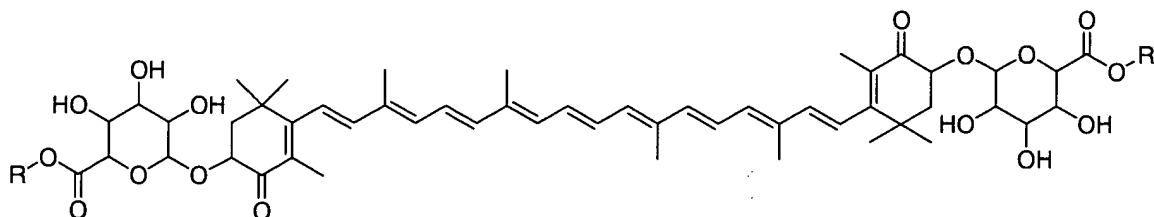
693. The method of claim 664, wherein the carotenoid derivative is a derivative of a  
naturally occurring carotenoid, and wherein the naturally occurring carotenoid is  
lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or  
15 canthaxanthin.

694. The method of claim 664, wherein the carotenoid derivative having the structure



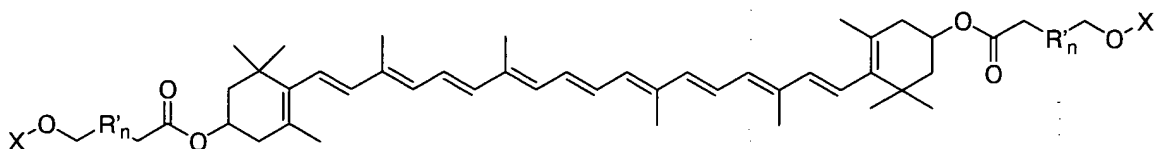
where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

- 5 695. The method of claim 664, wherein the carotenoid derivative having the structure



- where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
10 H, alkyl, or aryl.

696. The method of claim 664, wherein the carotenoid derivative having the structure



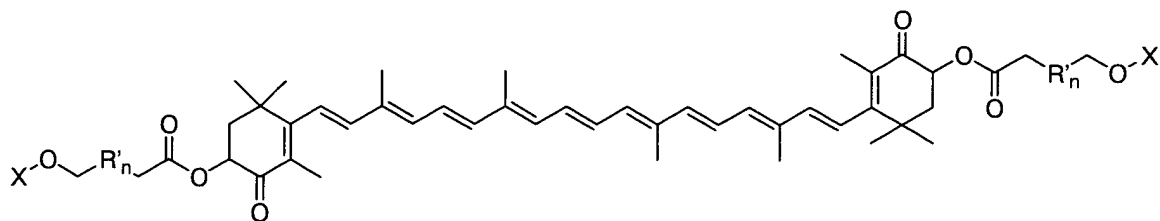
- 15 where each X is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

where each R' is independently -alkyl-O, alkyl, or aryl; and

20

where n is between about 0 and 12.

697. The method of claim 664, wherein the carotenoid derivative having the structure



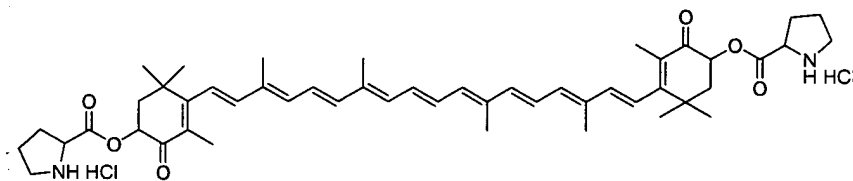
where each X is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
 5 H, alkyl, or aryl;

where each R' is independently -alkyl-O, alkyl, or aryl; and

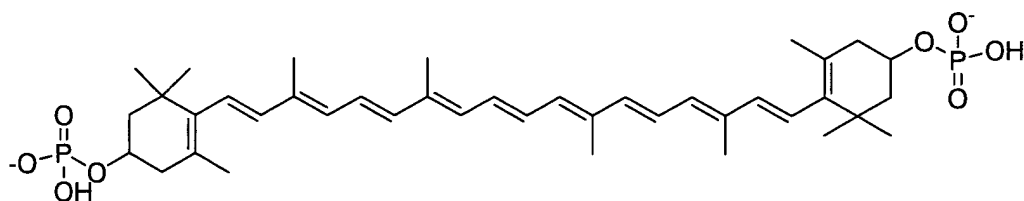
where n is between about 0 and 12.

10

698. The method of claim 664, wherein the carotenoid derivative having the structure

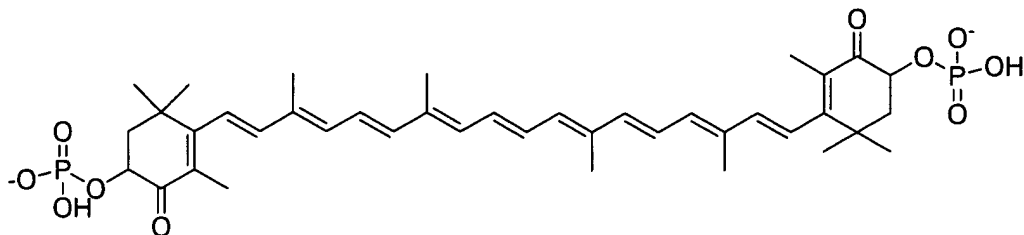


699. The method of claim 664, wherein the carotenoid derivative having the structure

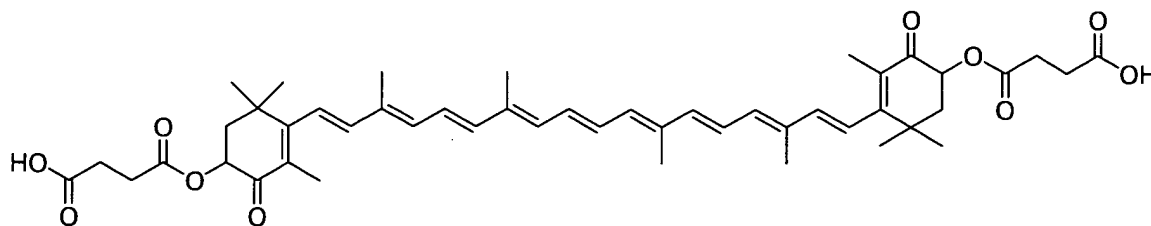


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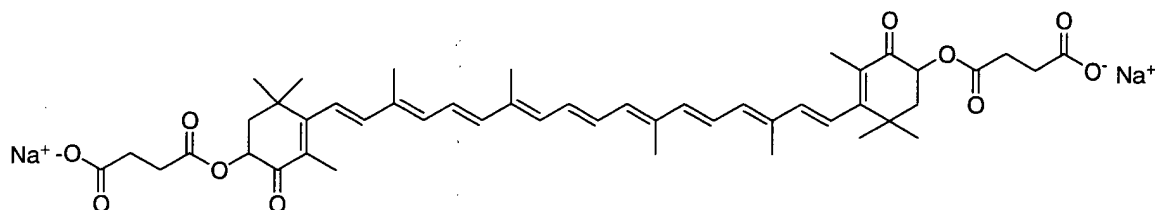
700. The method of claim 664, wherein the carotenoid derivative having the structure



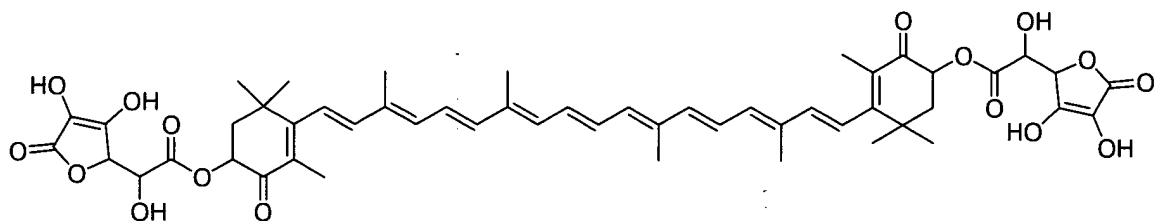
701. The method of claim 664, wherein the carotenoid derivative having the structure



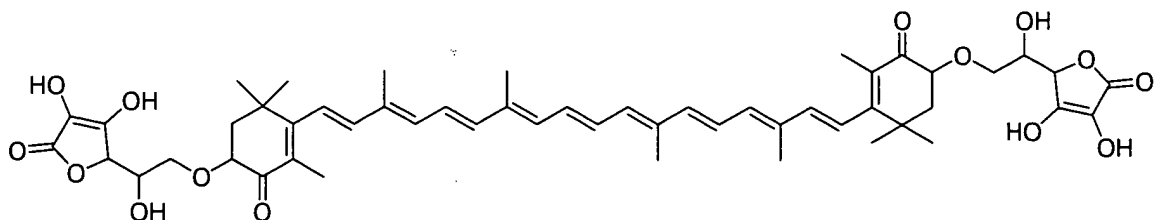
702. The method of claim 664, wherein the carotenoid derivative having the structure



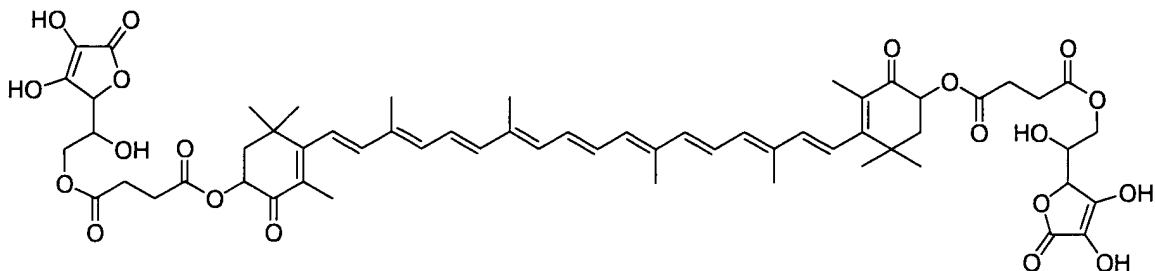
703. The method of claim 664, wherein the carotenoid derivative having the structure



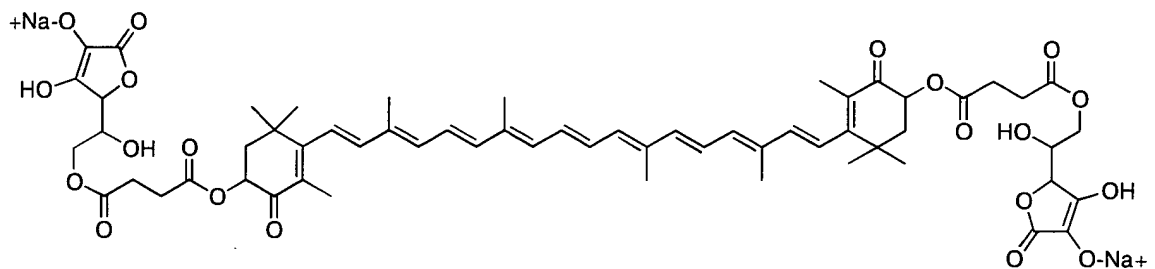
704. The method of claim 664, wherein the carotenoid derivative having the structure



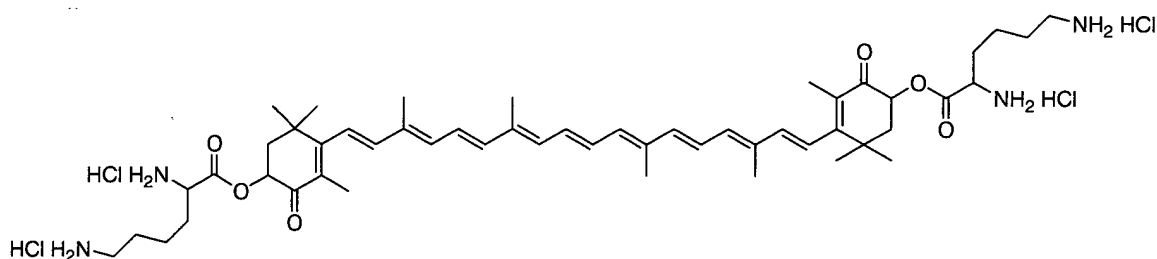
705. The method of claim 664, wherein the carotenoid derivative having the structure



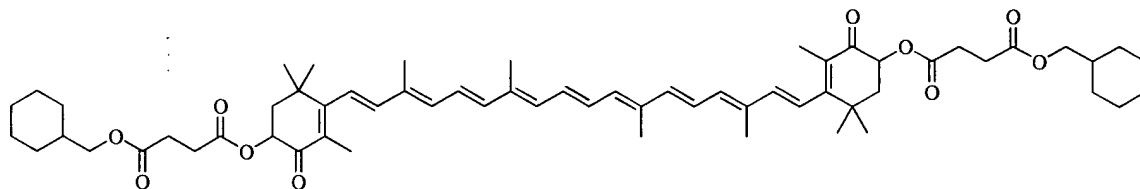
706. The method of claim 664, wherein the carotenoid derivative having the structure



5 707. The method of claim 664, wherein the carotenoid derivative having the structure

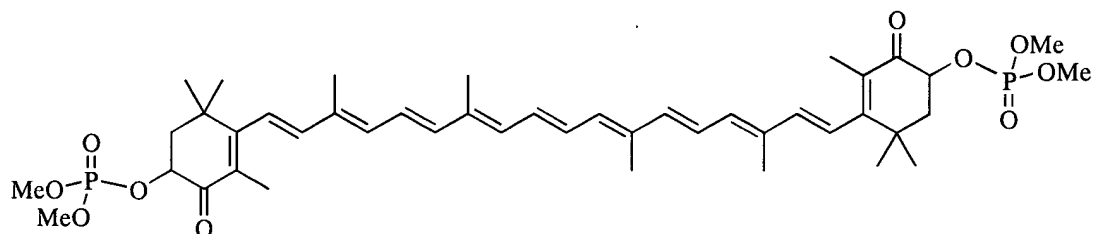


708. The method of claim 664, wherein the carotenoid derivative having the structure

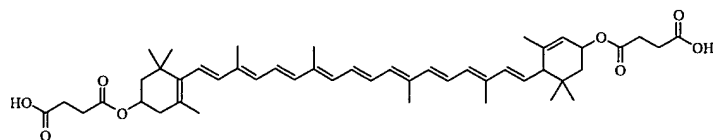


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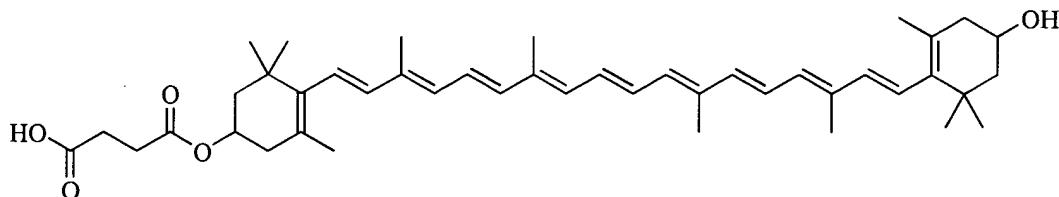
709. The method of claim 664, wherein the carotenoid derivative having the structure



710. The method of claim 664, wherein the carotenoid derivative having the structure

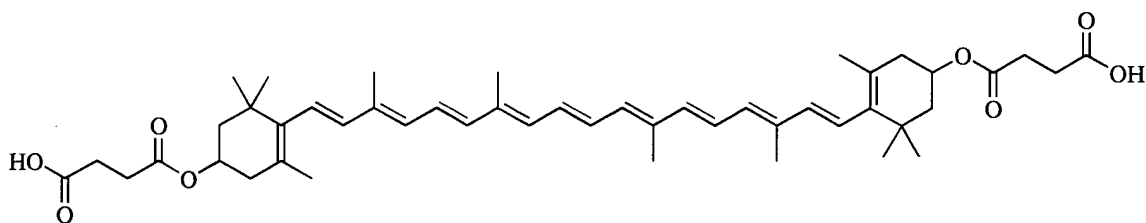


711. The method of claim 664, wherein the carotenoid derivative having the structure

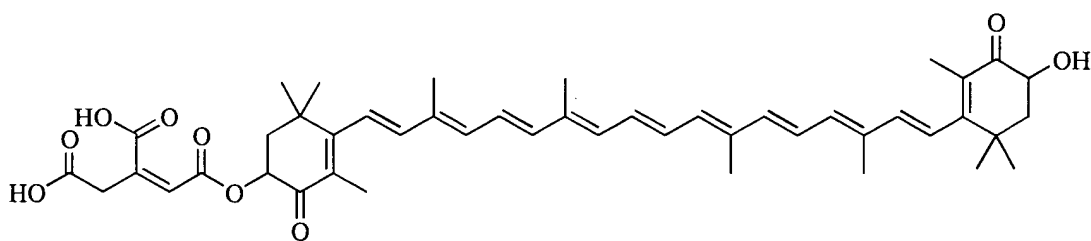


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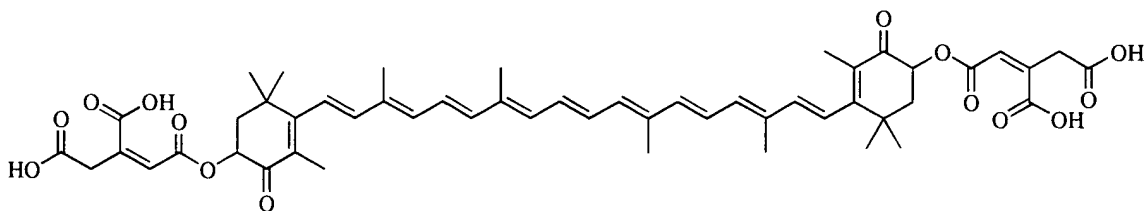
712. The method of claim 664, wherein the carotenoid derivative having the structure



10 713. The method of claim 664, wherein the carotenoid derivative having the structure

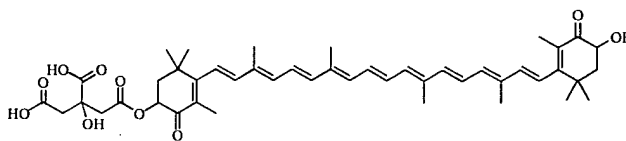


714. The method of claim 664, wherein the carotenoid derivative having the structure

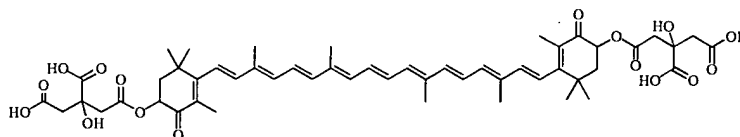


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715. The method of claim 664, wherein the carotenoid derivative having the structure

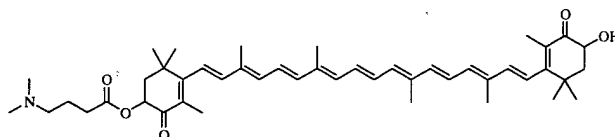


716. The method of claim 664, wherein the carotenoid derivative having the structure

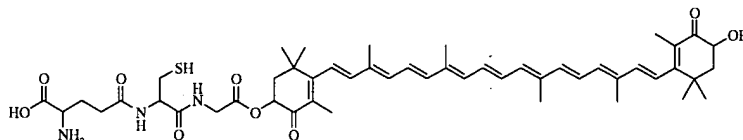


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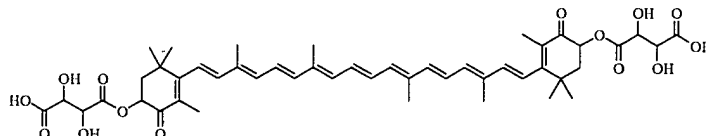
717. The method of claim 664, wherein the carotenoid derivative having the structure



10 718. The method of claim 664, wherein the carotenoid derivative having the structure

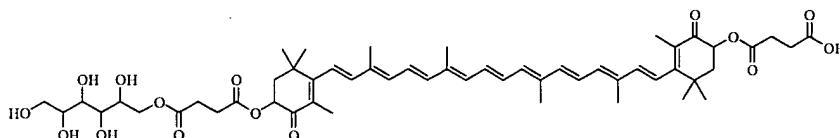


719. The method of claim 664, wherein the carotenoid derivative having the structure

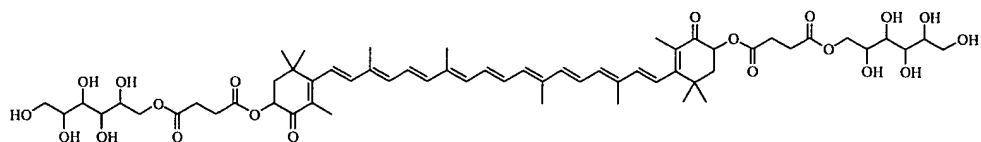


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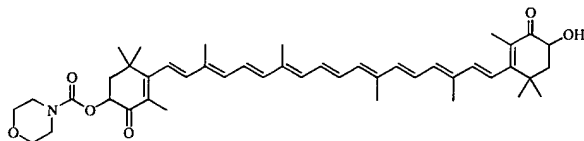
720. The method of claim 664, wherein the carotenoid derivative having the structure



721. The method of claim 664, wherein the carotenoid derivative having the structure

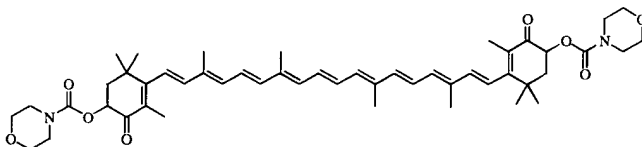


722. The method of claim 664, wherein the carotenoid derivative having the structure

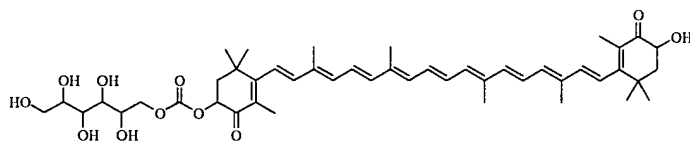


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723. The method of claim 664, wherein the carotenoid derivative having the structure

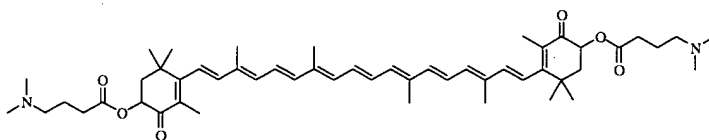


724. The method of claim 664, wherein the carotenoid derivative having the structure

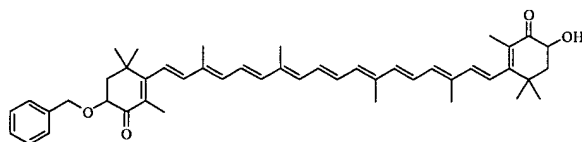


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725. The method of claim 664, wherein the carotenoid derivative having the structure

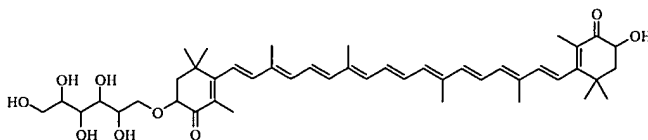


15 726. The method of claim 664, wherein the carotenoid derivative having the structure

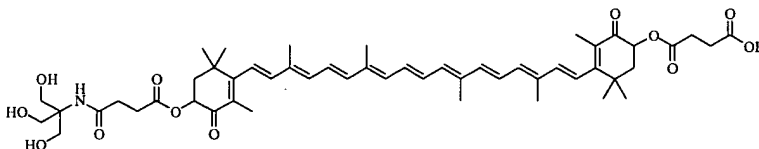


727. The method of claim 664, wherein the carotenoid derivative having the structure



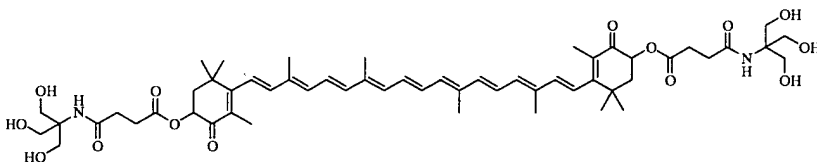


728. The method of claim 664, wherein the carotenoid derivative having the structure

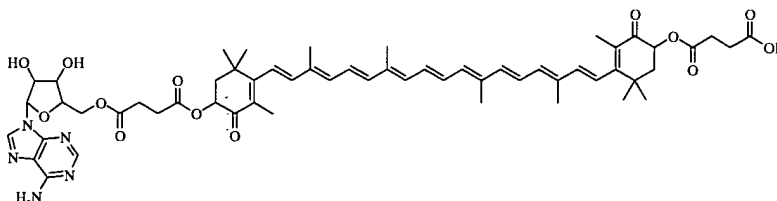


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729. The method of claim 664, wherein the carotenoid derivative having the structure

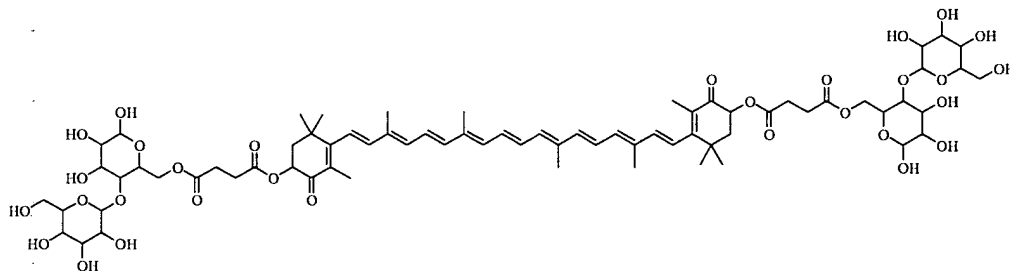


730. The method of claim 664, wherein the carotenoid derivative having the structure

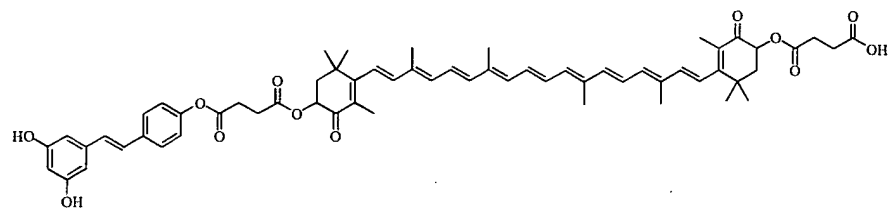


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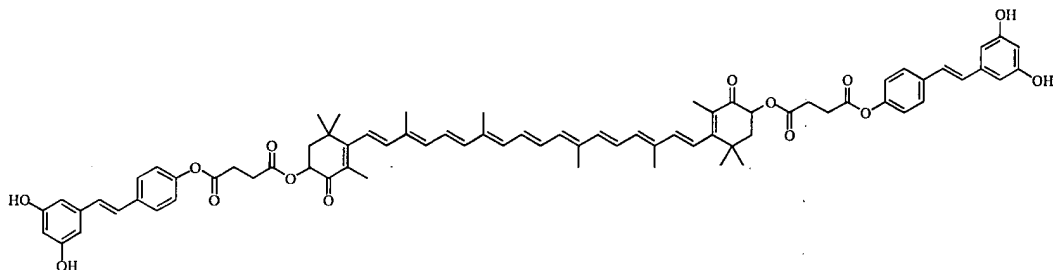
731. The method of claim 664, wherein the carotenoid derivative having the structure



15 732. The method of claim 664, wherein the carotenoid derivative having the structure



733. The method of claim 664, wherein the carotenoid derivative having the structure



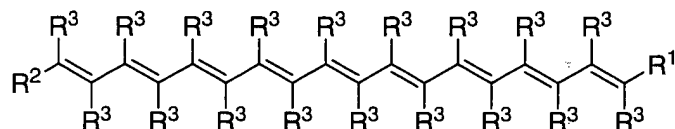
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734. A method of treating cancerous and pre-cancerous cell(s) with a chemical composition comprising a carotenoid derivative, comprising:

administering the carotenoid derivative to a subject;

10

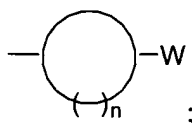
wherein the carotenoid derivative has the structure



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where each  $R^3$  is independently hydrogen or methyl;

where  $R^1$  and  $R^2$  are independently H, an acyclic alkene comprising at least one substituent, or a cyclic ring comprising at least one substituent, wherein the cyclic ring having general structure:



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where n is 4 to 10 carbon atoms; and

where W is the substituent; and

increasing *connexin 43* expression.

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735. The method of claim 734, wherein each of the substituents –W independently comprises –XR, wherein each X independently comprises O, N, or S.

736. The method of claim 734, wherein each of the substituents –W independently comprises amino acids, esters, carbamates, amides, carbonates, alcohol, phosphates, or sulfonates.

737. The method of claim 734, wherein the carotenoid derivative is at least partially water soluble.

738. The method of claim 734, wherein the substituent is at least partially hydrophilic.

739. The method of claim 734, further comprising reducing a proliferation rate of cancerous and pre-cancerous cell(s).

740. The method of claim 734, further comprising reducing a proliferation rate of cancerous cell(s), wherein cancerous cell(s) comprise carcinogen-initiated cell(s).

741. The method of claim 734, further comprising increasing intercellular gap junctional communication.

742. The method of claim 734, wherein the subject is a mammal.

743. The method of claim 734, wherein the subject is human.

744. The method of claim 734, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally.

5

745. The method of claim 734, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 5 to 300 mg per day.

10 746. The method of claim 734, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 0.25 mg to 1.0 g per day.

15 747. The method of claim 734, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject.

20 748. The method of claim 734, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 5 to 300 mg per day.

25 749. The method of claim 734, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 0.25 mg to 1.0 g per day.

750. The method of claim 734, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject subcutaneously.

30 751. The method of claim 734, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally.

752. The method of claim 734, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 5 to 100 mg per day.

5

753. The method of claim 734, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 0.25 mg to 1.0 g per day.

10 754. The method of claim 734, wherein administering the carotenoid derivative to a subject comprises a dose in a range of about 0.25 mg to 1 g.

755. The method of claim 734, wherein administering the carotenoid derivative to a subject comprises at least two different carotenoid derivatives.

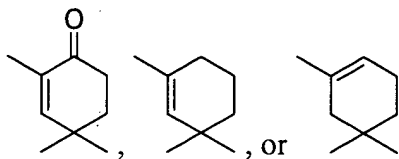
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756. The method of claim 734, wherein the cyclic ring further comprises at least one chiral center.

20

757. The method of claim 734, wherein the cyclic ring further comprises at least one degree of unsaturation.

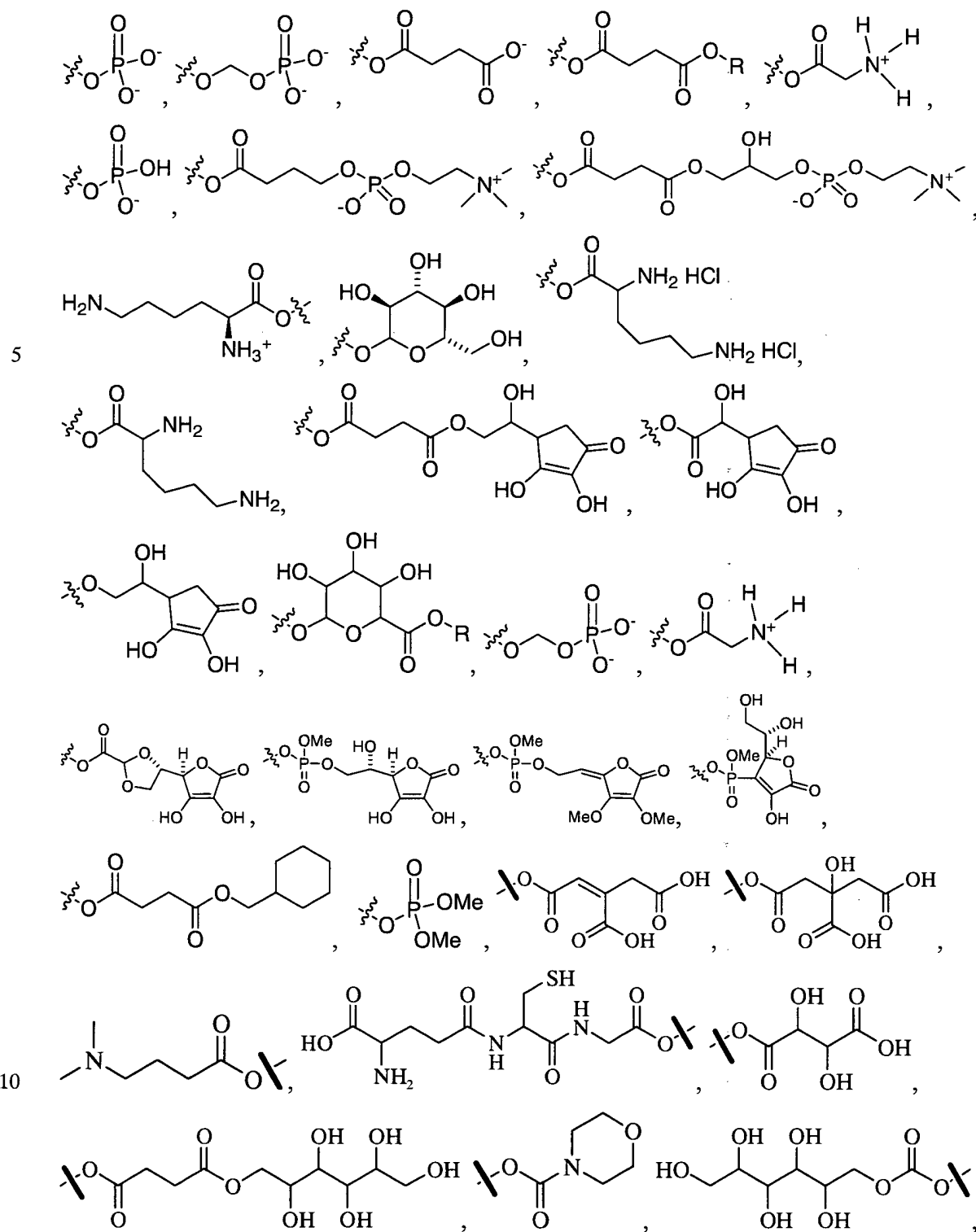
758. The method of claim 734, wherein each cyclic ring is independently

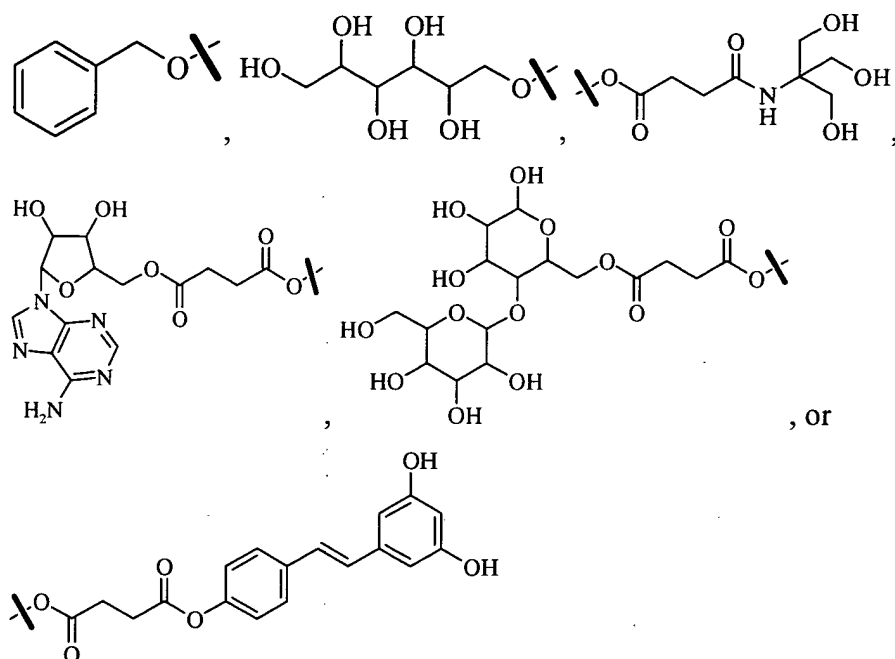


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759. The method of claim 734, wherein the substituent is a carboxylic acid, an ester, an alkanol, an amine, a phosphate, a succinate, a glycinate, an ether, a glucoside, a sugar, or a carboxylate salt.

760. The method of claim 734, wherein each substituent is independently

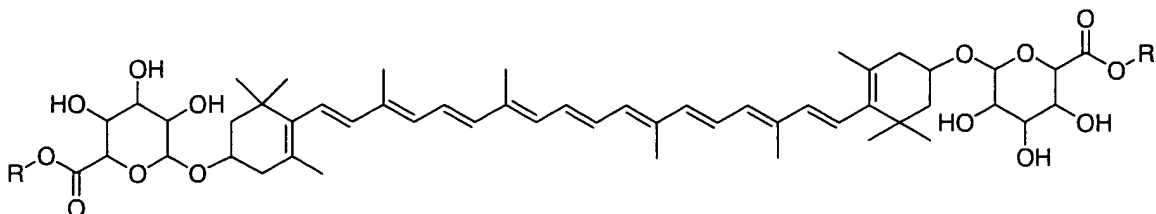




- 5 where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

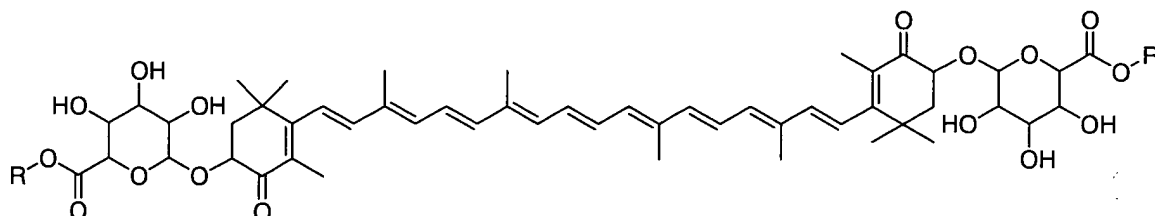
761. The method of claim 734, wherein the carotenoid derivative is a derivative of a  
 10 naturally occurring carotenoid.
762. The method of claim 734, wherein the carotenoid derivative is a derivative of a  
 naturally occurring carotenoid, and wherein the naturally occurring carotenoid is  
 lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or  
 15 canthaxanthin.

763. The method of claim 734, wherein the carotenoid derivative having the structure



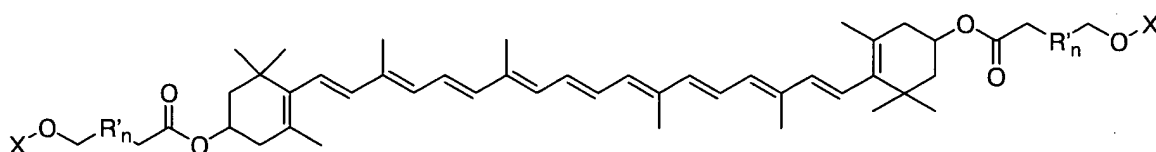
where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

- 5 764. The method of claim 734, wherein the carotenoid derivative having the structure



- where each R is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
10 H, alkyl, or aryl.

765. The method of claim 734, wherein the carotenoid derivative having the structure



- 15 where each X is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

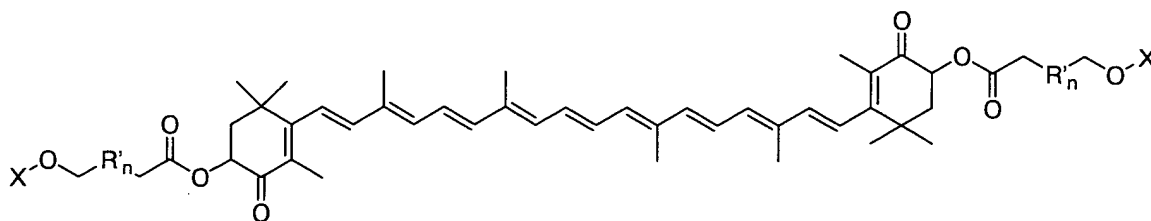
where each R' is independently -alkyl-O, alkyl, or aryl; and

20

where n is between about 0 and 12.

766. The method of claim 734, wherein the carotenoid derivative having the structure





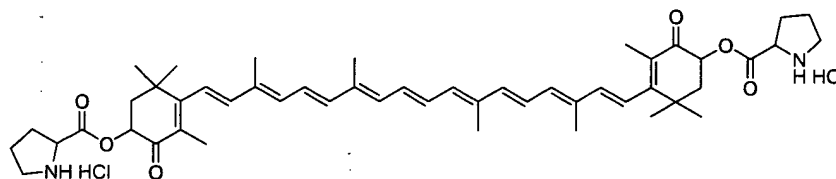
where each X is independently -alkyl-NR<sub>3</sub><sup>1+</sup>, -aromatic-NR<sub>3</sub><sup>1+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran,  
 5 H, alkyl, or aryl;

where each R' is independently -alkyl-O, alkyl, or aryl; and

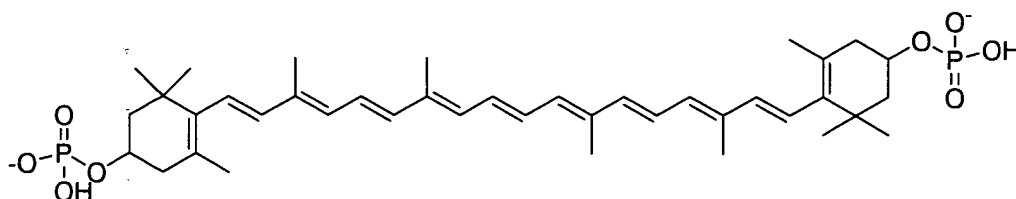
where n is between about 0 and 12.

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767. The method of claim 734, wherein the carotenoid derivative having the structure

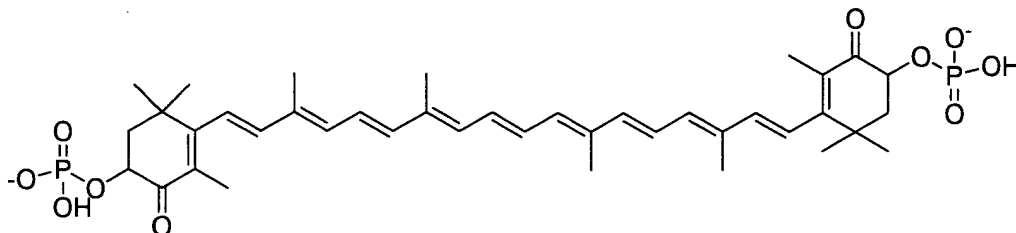


768. The method of claim 734, wherein the carotenoid derivative having the structure

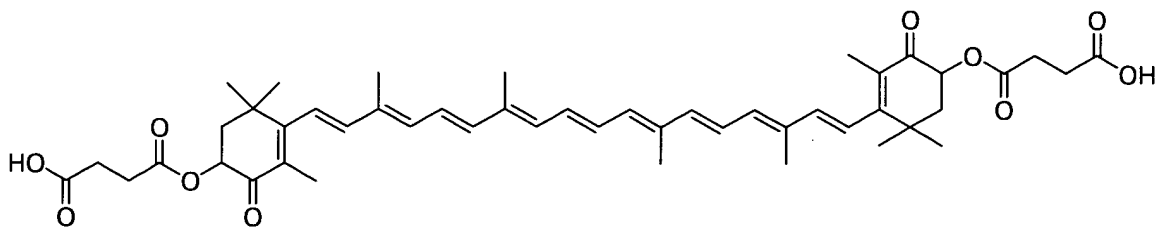


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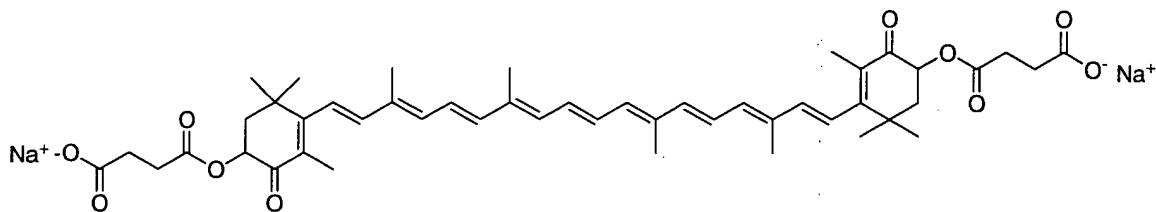
769. The method of claim 734, wherein the carotenoid derivative having the structure



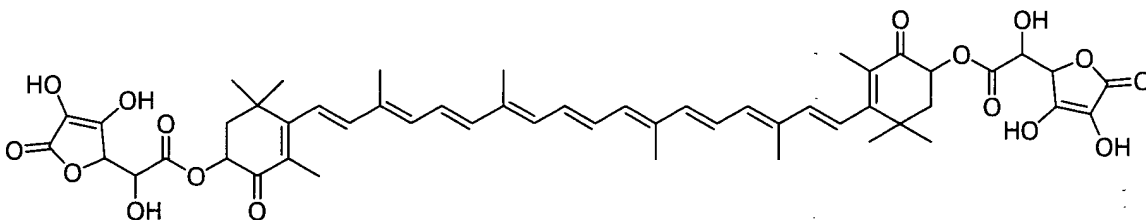
770. The method of claim 734, wherein the carotenoid derivative having the structure



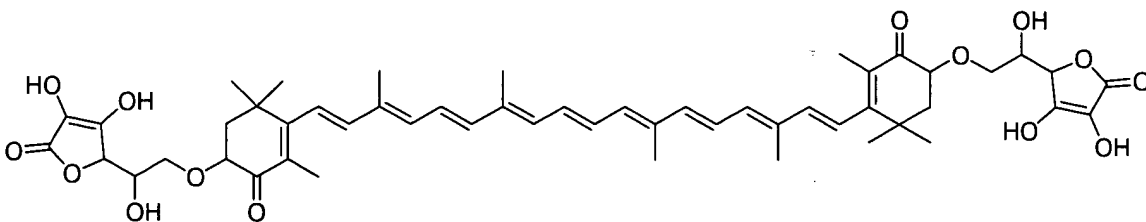
771. The method of claim 734, wherein the carotenoid derivative having the structure



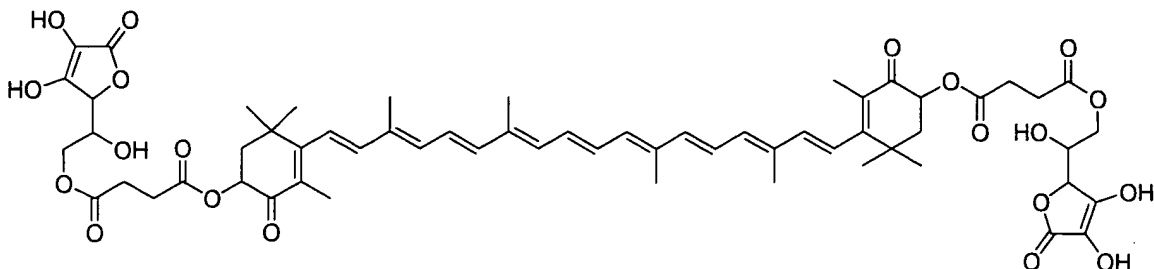
772. The method of claim 734, wherein the carotenoid derivative having the structure



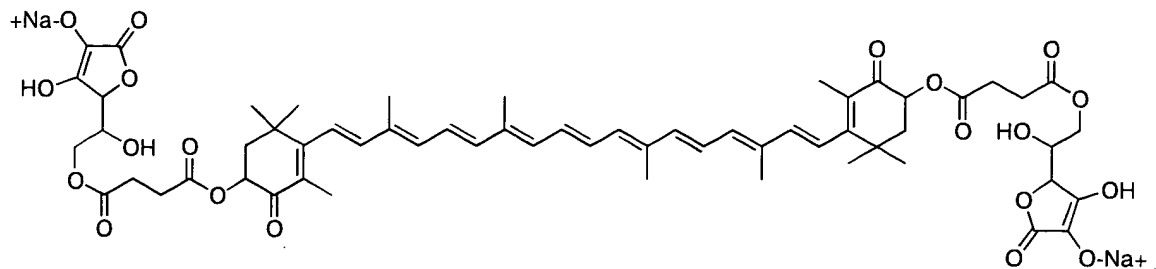
773. The method of claim 734, wherein the carotenoid derivative having the structure



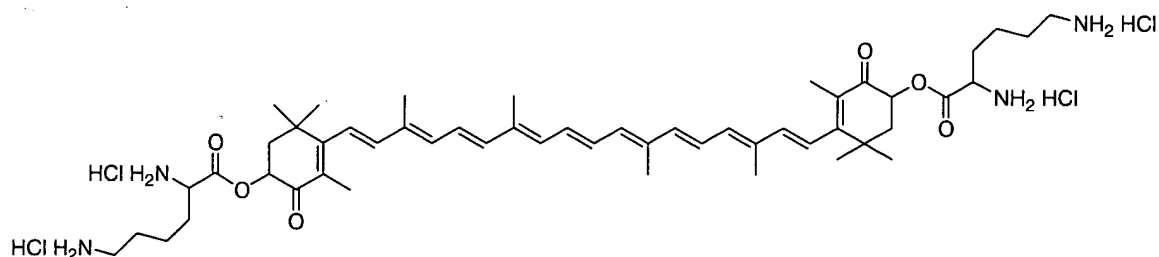
774. The method of claim 734, wherein the carotenoid derivative having the structure



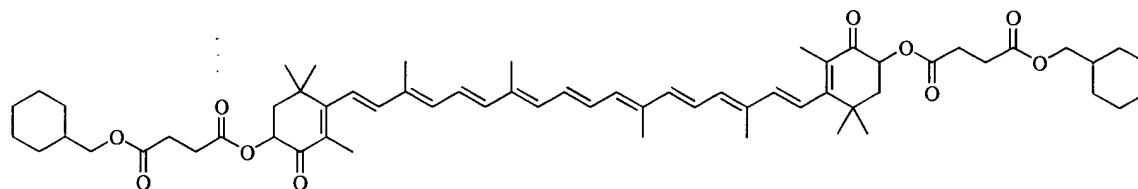
775. The method of claim 734, wherein the carotenoid derivative having the structure



5 776. The method of claim 734, wherein the carotenoid derivative having the structure

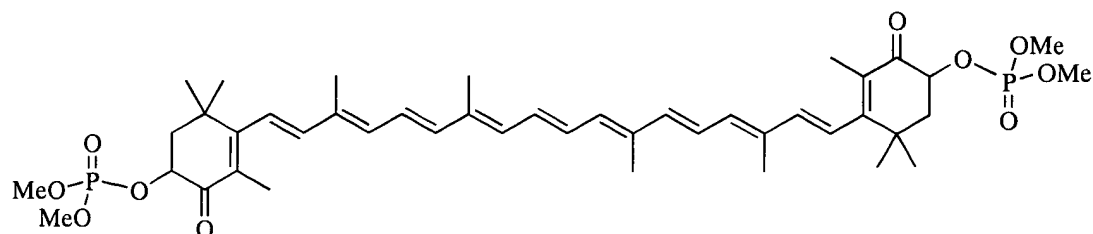


777. The method of claim 734, wherein the carotenoid derivative having the structure

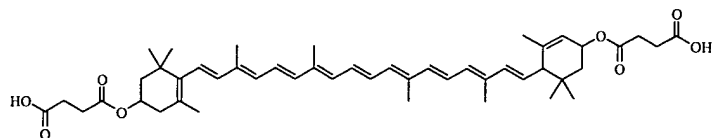


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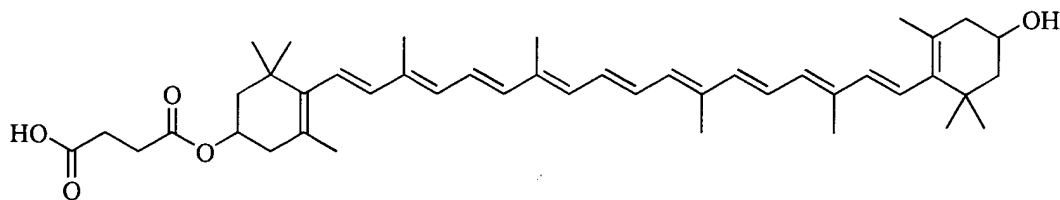
778. The method of claim 734, wherein the carotenoid derivative having the structure



779. The method of claim 734, wherein the carotenoid derivative having the structure

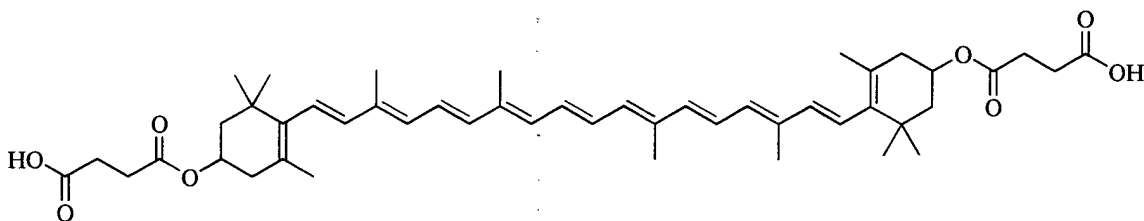


780. The method of claim 734, wherein the carotenoid derivative having the structure

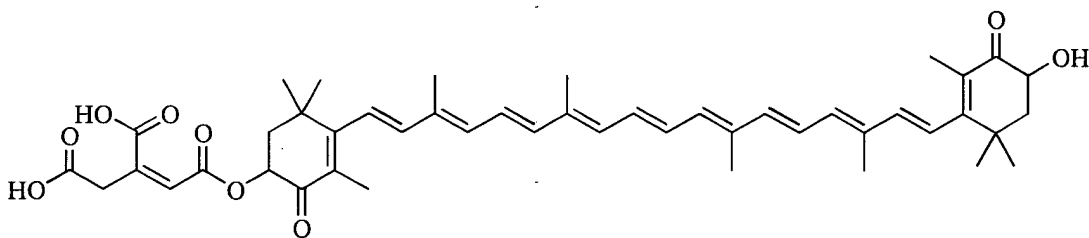


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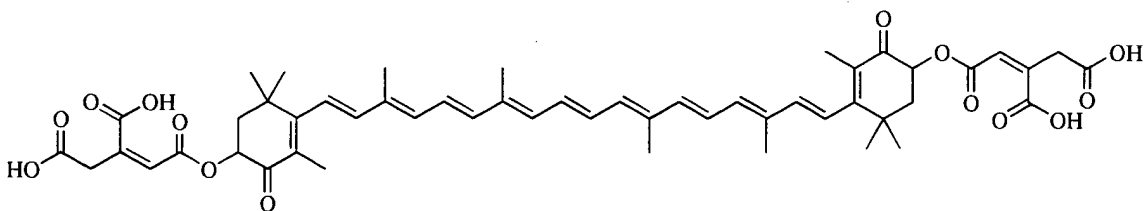
781. The method of claim 734, wherein the carotenoid derivative having the structure



10 782. The method of claim 734, wherein the carotenoid derivative having the structure

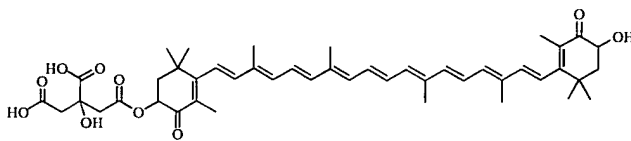


783. The method of claim 734, wherein the carotenoid derivative having the structure

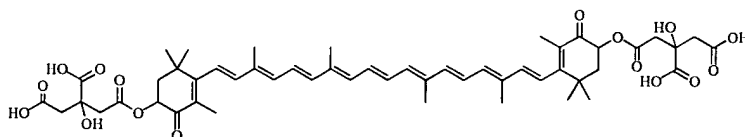


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784. The method of claim 734, wherein the carotenoid derivative having the structure

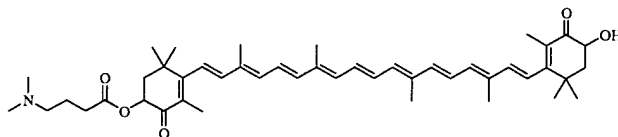


785. The method of claim 734, wherein the carotenoid derivative having the structure

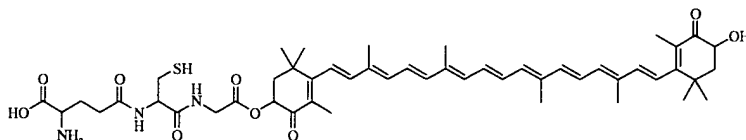


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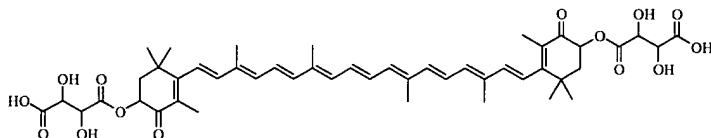
786. The method of claim 734, wherein the carotenoid derivative having the structure



10 787. The method of claim 734, wherein the carotenoid derivative having the structure

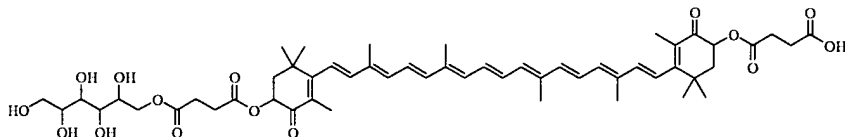


788. The method of claim 734, wherein the carotenoid derivative having the structure

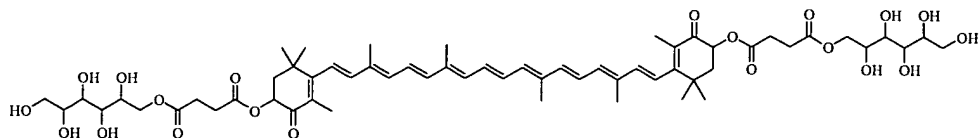


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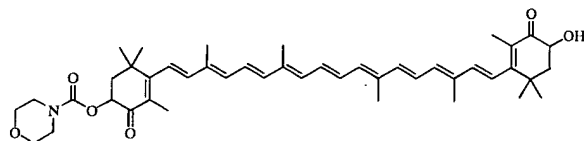
789. The method of claim 734, wherein the carotenoid derivative having the structure



790. The method of claim 734, wherein the carotenoid derivative having the structure

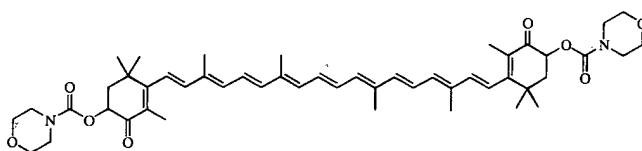


791. The method of claim 734, wherein the carotenoid derivative having the structure

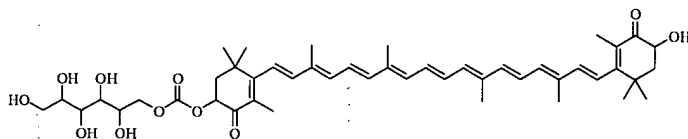


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792. The method of claim 734, wherein the carotenoid derivative having the structure

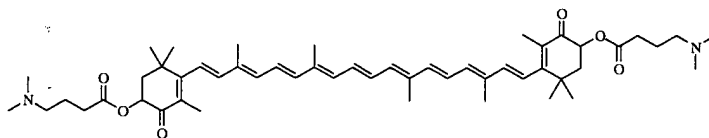


793. The method of claim 734, wherein the carotenoid derivative having the structure

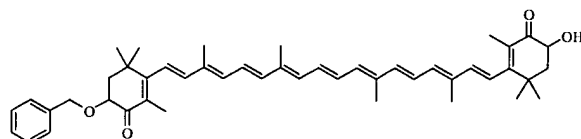


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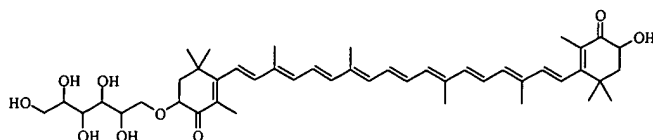
794. The method of claim 734, wherein the carotenoid derivative having the structure



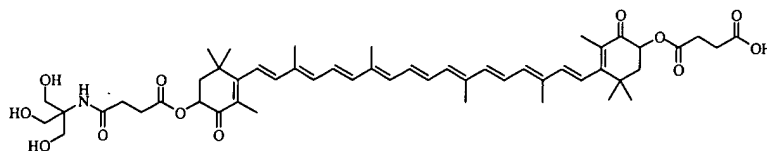
15 795. The method of claim 734, wherein the carotenoid derivative having the structure



796. The method of claim 734, wherein the carotenoid derivative having the structure

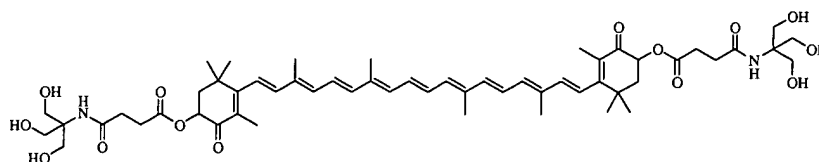


797. The method of claim 734, wherein the carotenoid derivative having the structure

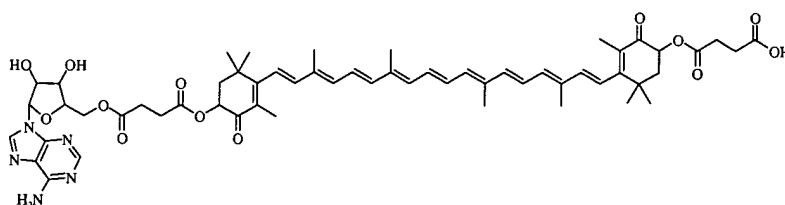


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798. The method of claim 734, wherein the carotenoid derivative having the structure

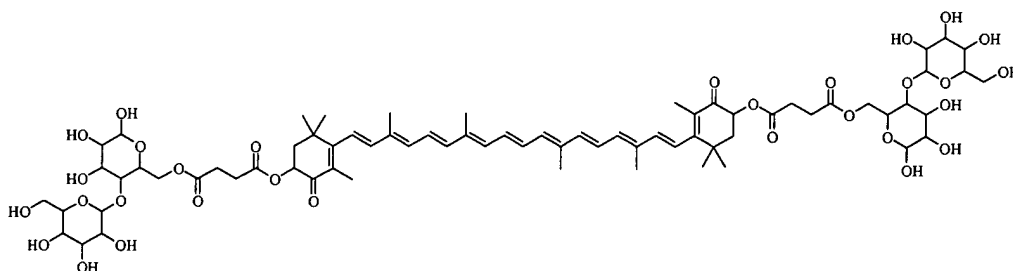


799. The method of claim 734, wherein the carotenoid derivative having the structure

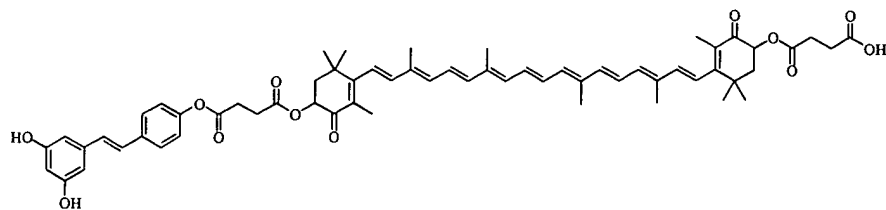


10

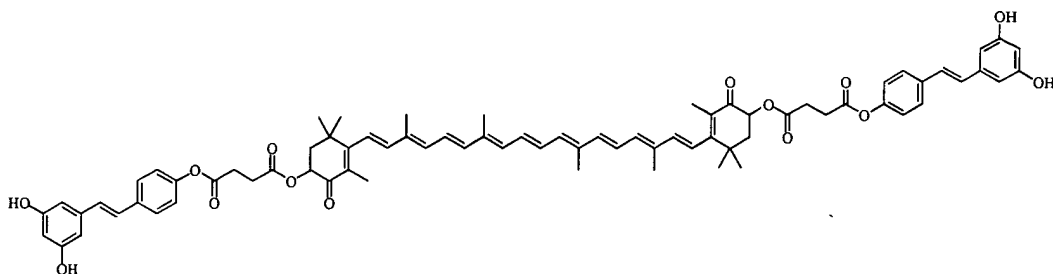
800. The method of claim 734, wherein the carotenoid derivative having the structure



15 801. The method of claim 734, wherein the carotenoid derivative having the structure



802. The method of claim 734, wherein the carotenoid derivative having the structure



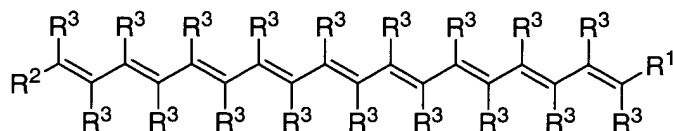
5

803. A method of treating arrhythmia with a chemical composition comprising a carotenoid derivative, comprising:

administering the carotenoid derivative to a subject;

10

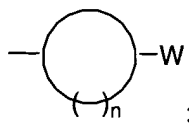
wherein the carotenoid derivative has the structure



15

where each  $R^3$  is independently hydrogen or methyl;

where  $R^1$  and  $R^2$  are independently H, an acyclic alkene comprising at least one substituent, or a cyclic ring comprising at least one substituent, wherein the cyclic ring having general structure:



20



where n is 4 to 10 carbon atoms; and

where W is the substituent; and

5

increasing *connexin 43* expression.

804. The method of claim 803, wherein each of the substituents –W independently comprises –XR, wherein each X independently comprises O, N, or S.

10

805. The method of claim 803, wherein each of the substituents –W independently comprises amino acids, esters, carbamates, amides, carbonates, alcohol, phosphates, or sulfonates.

15 806. The method of claim 803, wherein the carotenoid derivative is at least partially water soluble.

807. The method of claim 803, wherein the substituent is at least partially hydrophilic.

20 808. The method of claim 803, further comprising increasing intercellular gap junctional communication.

809. The method of claim 803, wherein the subject is a mammal.

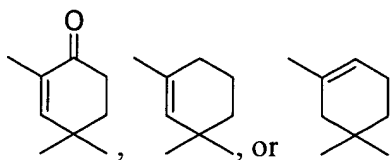
25 810. The method of claim 803, wherein the subject is human.

811. The method of claim 803, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally.

30

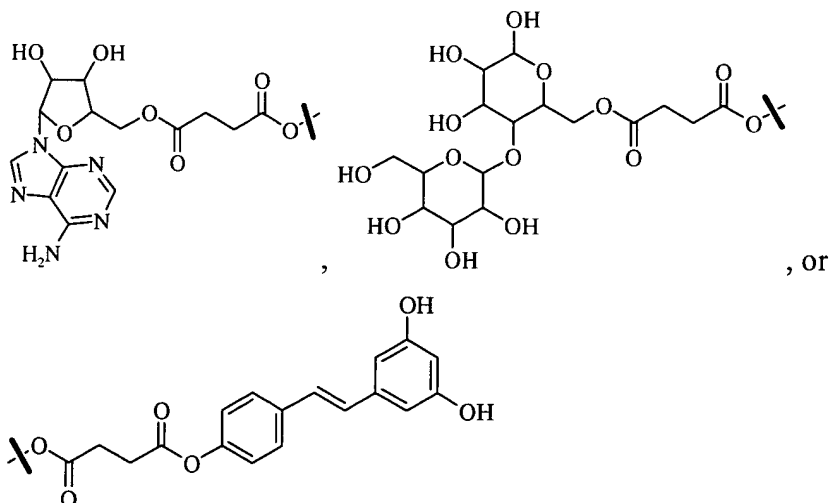
812. The method of claim 803, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 5 to 300 mg per day.
- 5 813. The method of claim 803, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 0.25 mg to 1.0 g per day.
- 10 814. The method of claim 803, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject.
- 15 815. The method of claim 803, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 5 to 300 mg per day.
- 20 816. The method of claim 803, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 0.25 mg to 1.0 g per day.
- 25 817. The method of claim 803, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject subcutaneously.
- 30 818. The method of claim 803, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally.
819. The method of claim 803, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 5 to 100 mg per day.

820. The method of claim 803, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 0.25 mg to 1.0 g per day.
- 5 821. The method of claim 803, wherein administering the carotenoid derivative to a subject comprises a dose in a range of about 0.25 mg to 1 g.
822. The method of claim 803, wherein administering the carotenoid derivative to a subject comprises at least two different carotenoid derivatives.
- 10 823. The method of claim 803, wherein the cyclic ring further comprises at least one chiral center.
824. The method of claim 803, wherein the cyclic ring further comprises at least one
- 15 degree of unsaturation.
825. The method of claim 803, wherein each cyclic ring is independently



- 20 826. The method of claim 803, wherein the substituent is a carboxylic acid, an ester, an alkanol, an amine, a phosphate, a succinate, a glycinate, an ether, a glucoside, a sugar, or a carboxylate salt.
- 25 827. The method of claim 803, wherein each substituent is independently



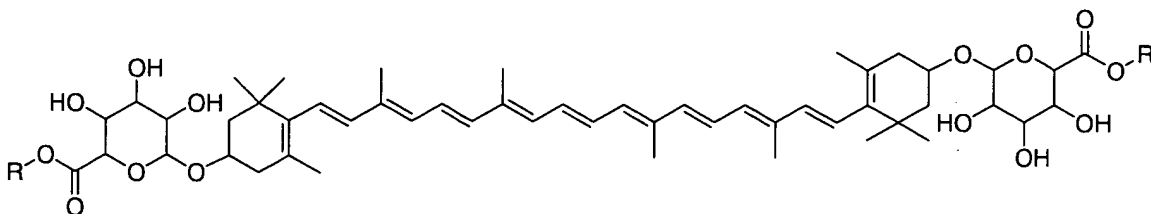


where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

828. The method of claim 803, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid.

829. The method of claim 803, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid, and wherein the naturally occurring carotenoid is lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or canthaxanthin.

830. The method of claim 803, wherein the carotenoid derivative having the structure

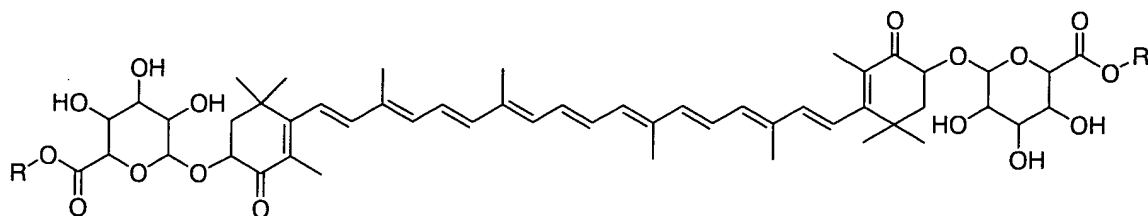


where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

Atty. Dkt. No.: 5777-00201

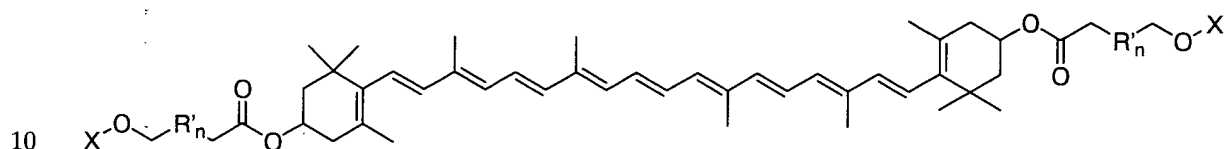
Meyertons, Hood, Kivlin,  
Kowert & Goetzel, P.C.

831. The method of claim 803, wherein the carotenoid derivative having the structure



5 where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

832. The method of claim 803, wherein the carotenoid derivative having the structure



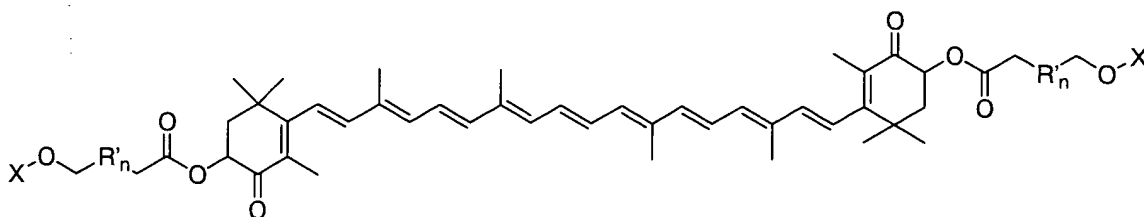
where each X is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

15

where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

20 833. The method of claim 803, wherein the carotenoid derivative having the structure



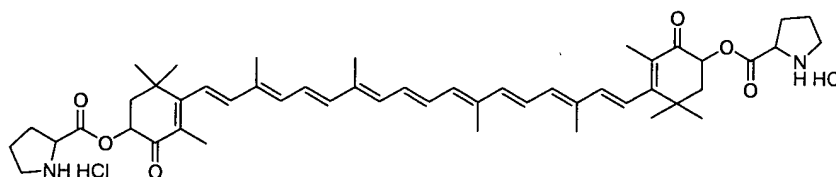
where each X is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

5 where each R' is independently -alkyl-O, alkyl, or aryl; and

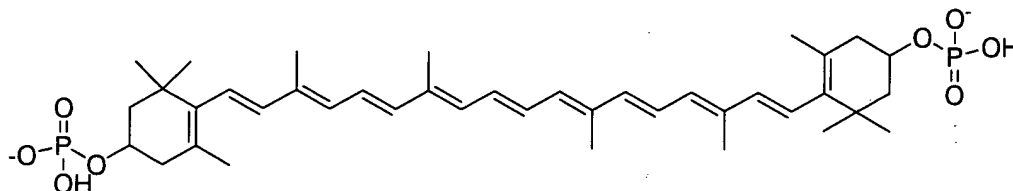
where n is between about 0 and 12.

834. The method of claim 803, wherein the carotenoid derivative having the structure

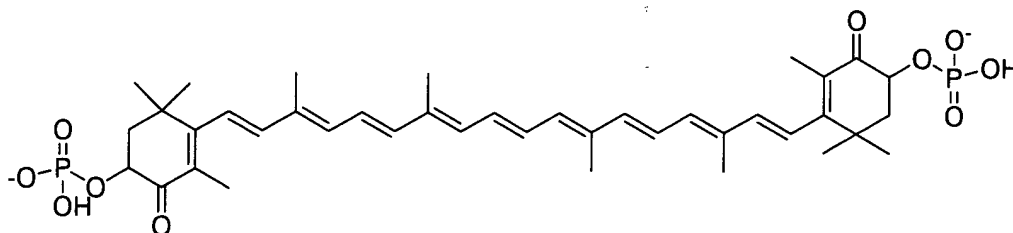
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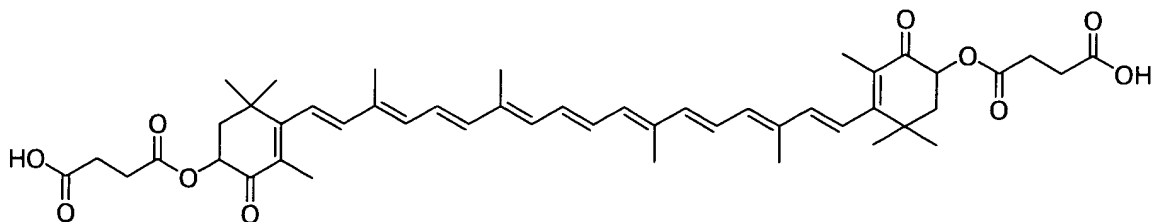
835. The method of claim 803, wherein the carotenoid derivative having the structure



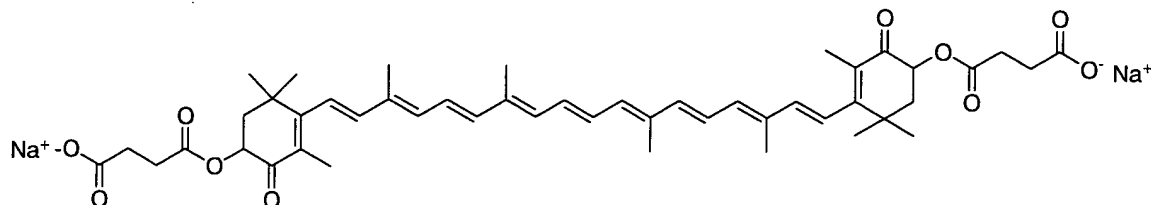
15 836. The method of claim 803, wherein the carotenoid derivative having the structure



837. The method of claim 803, wherein the carotenoid derivative having the structure

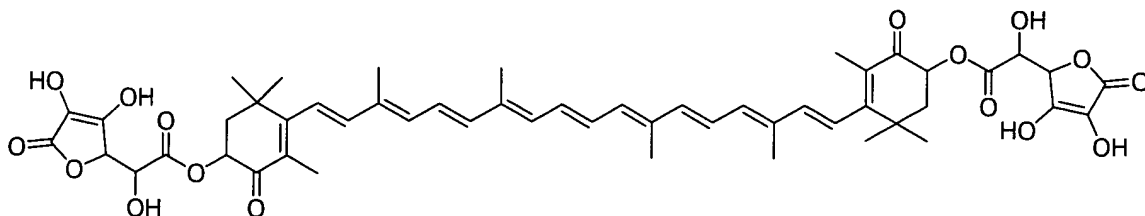


838. The method of claim 803, wherein the carotenoid derivative having the structure

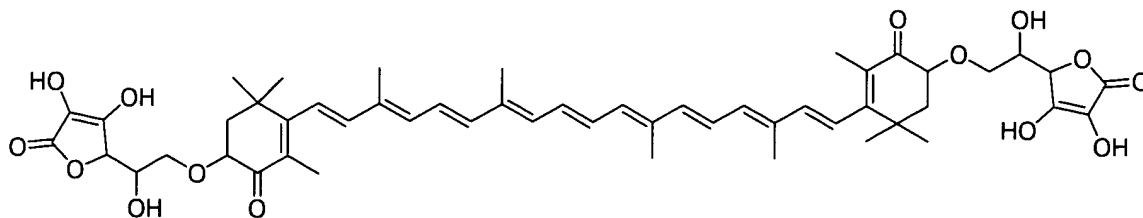


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839. The method of claim 803, wherein the carotenoid derivative having the structure

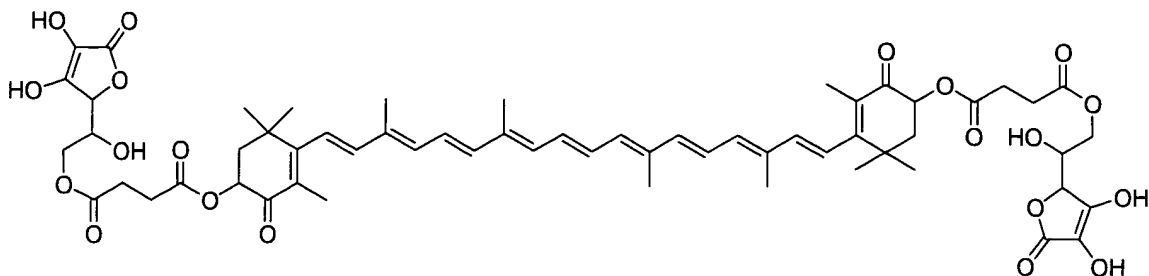


840. The method of claim 803, wherein the carotenoid derivative having the structure



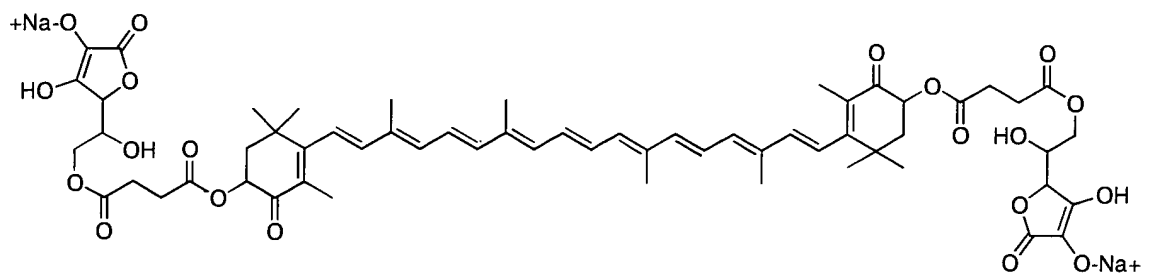
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841. The method of claim 803, wherein the carotenoid derivative having the structure

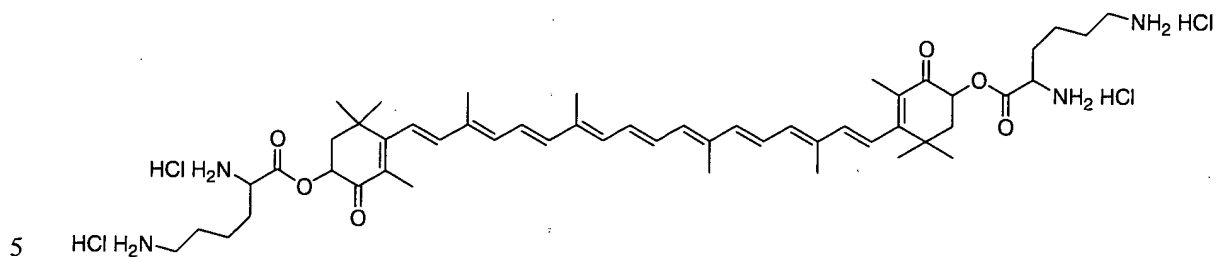




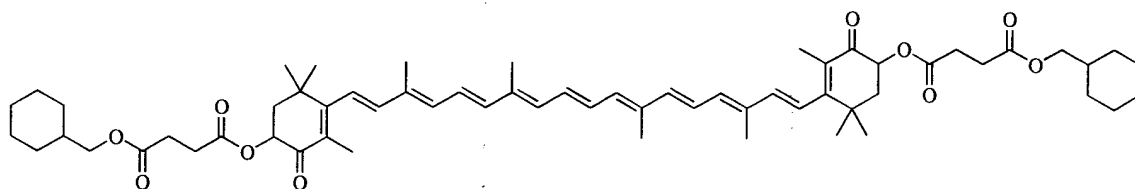
842. The method of claim 803, wherein the carotenoid derivative having the structure



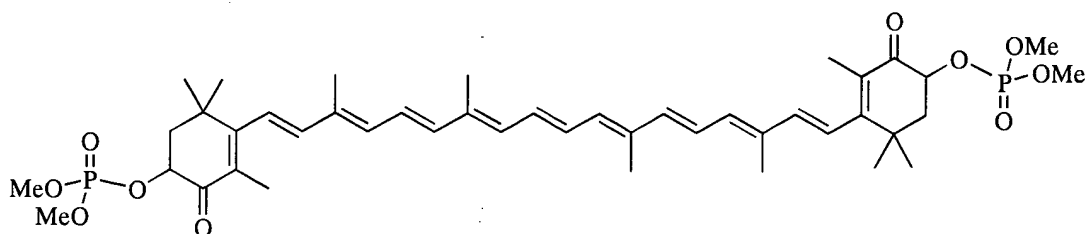
843. The method of claim 803, wherein the carotenoid derivative having the structure



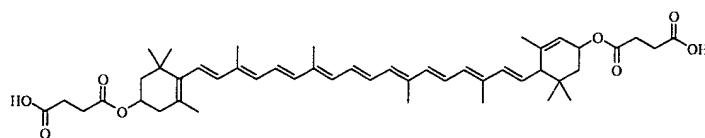
844. The method of claim 803, wherein the carotenoid derivative having the structure



845. The method of claim 803, wherein the carotenoid derivative having the structure



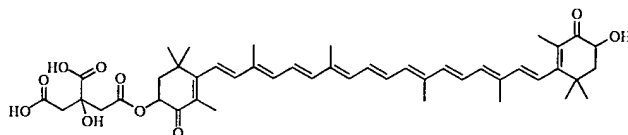
846. The method of claim 803, wherein the carotenoid derivative having the structure



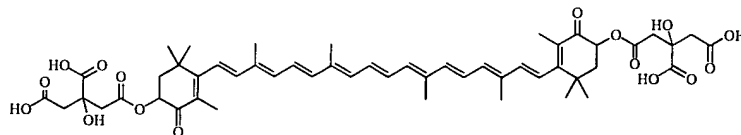
[illegible][illegible][illegible]OC(=O)CC(=O)C=C(C(=O)OC1C(=O)C(C)=C(C)C=C1C/C=C/C(C)/C=C/C(C)/C=C/C(C)/C=C/C(C)/C=C/C(C)/C=C/C(C)/C=C/C(C)/C=C1C(=O)C(C)=C(C)C=C1)C=C(C(=O)OC2C(=O)C(C)=C(C)C=C2C(=O)O)C(=O)O

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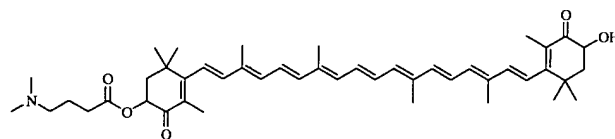


852. The method of claim 803, wherein the carotenoid derivative having the structure

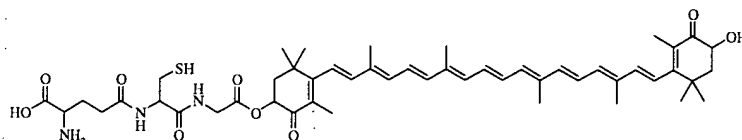


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853. The method of claim 803, wherein the carotenoid derivative having the structure

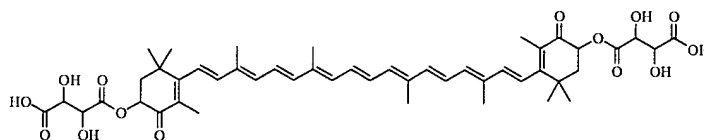


854. The method of claim 803, wherein the carotenoid derivative having the structure

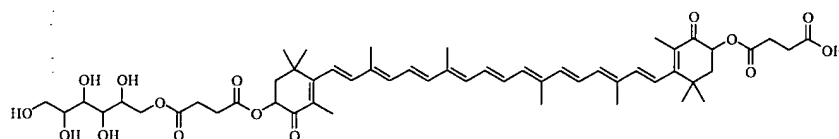


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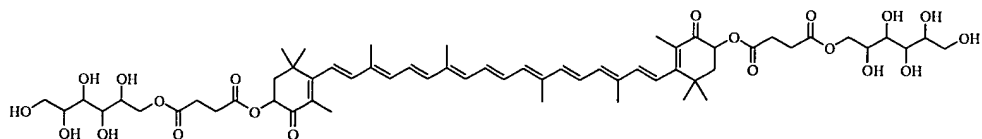
855. The method of claim 803, wherein the carotenoid derivative having the structure



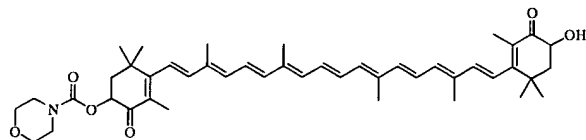
15 856. The method of claim 803, wherein the carotenoid derivative having the structure



857. The method of claim 803, wherein the carotenoid derivative having the structure

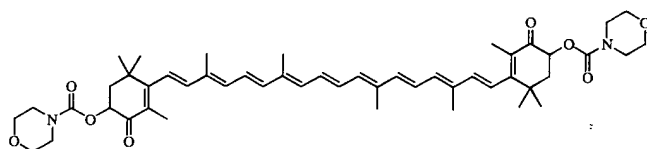


858. The method of claim 803, wherein the carotenoid derivative having the structure

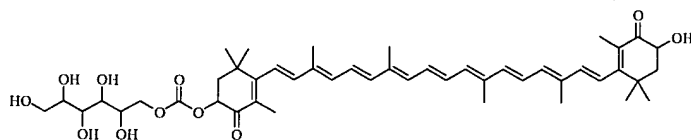


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859. The method of claim 803, wherein the carotenoid derivative having the structure

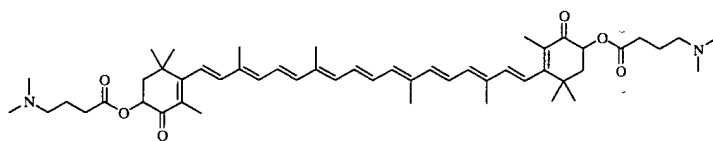


860. The method of claim 803, wherein the carotenoid derivative having the structure



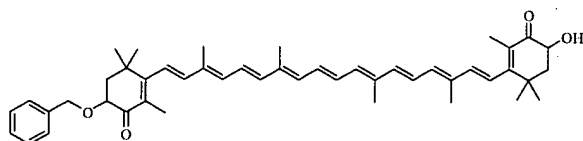
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861. The method of claim 803, wherein the carotenoid derivative having the structure

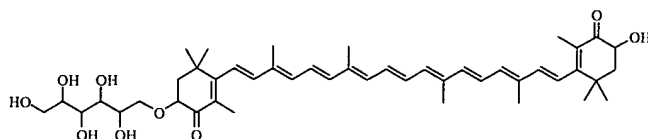


15

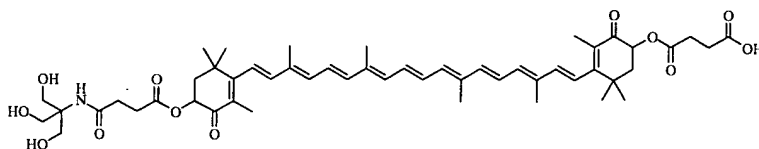
862. The method of claim 803, wherein the carotenoid derivative having the structure



863. The method of claim 803, wherein the carotenoid derivative having the structure

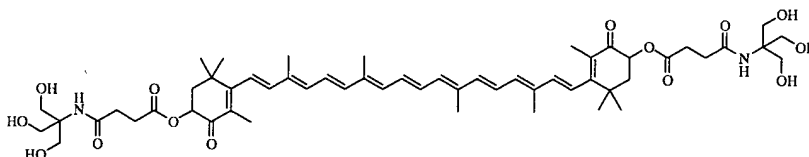


864. The method of claim 803, wherein the carotenoid derivative having the structure

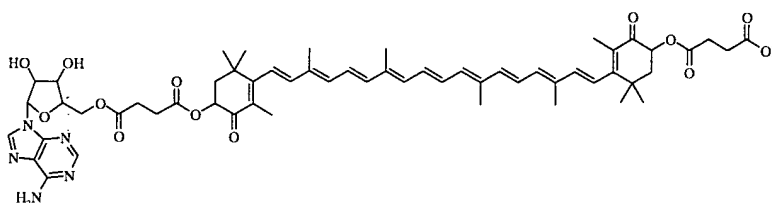


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865. The method of claim 803, wherein the carotenoid derivative having the structure

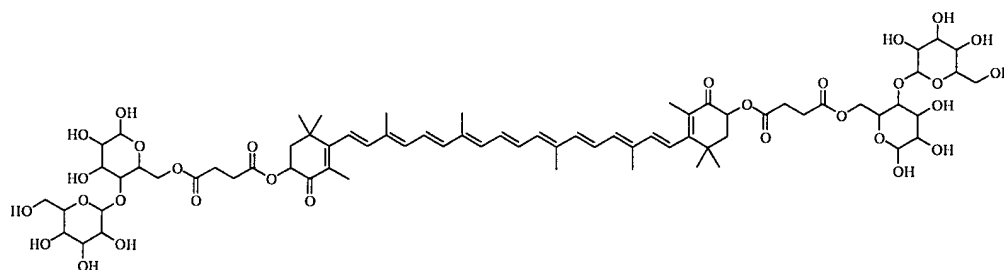


866. The method of claim 803, wherein the carotenoid derivative having the structure

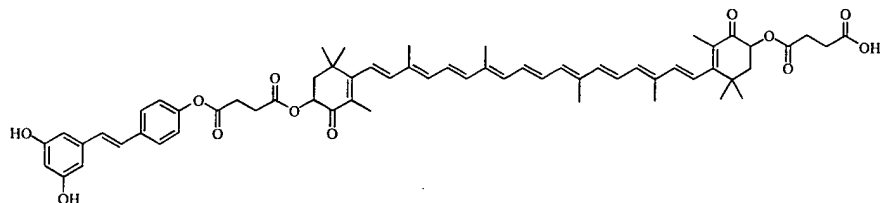


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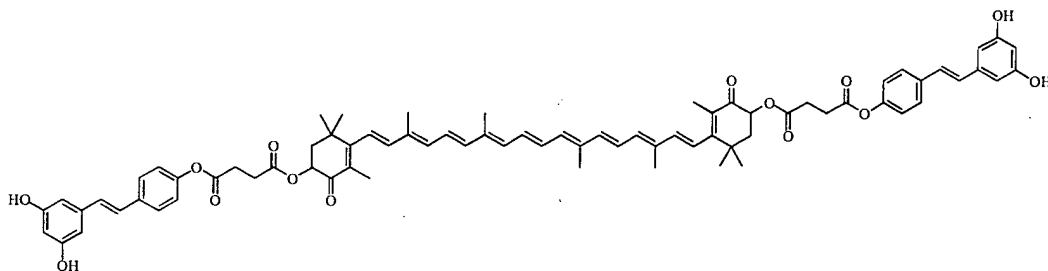
867. The method of claim 803, wherein the carotenoid derivative having the structure



15 868. The method of claim 803, wherein the carotenoid derivative having the structure



869. The method of claim 803, wherein the carotenoid derivative having the structure



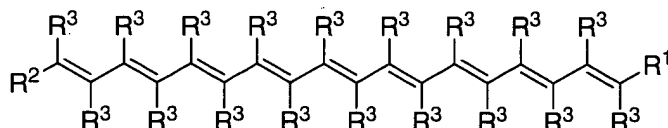
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870. A method of reducing C-reactive protein with a chemical composition comprising a carotenoid derivative, comprising:

10

administering the carotenoid derivative to a subject;

wherein the carotenoid derivative has the structure

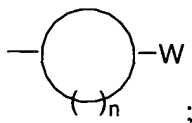


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where each  $R^3$  is independently hydrogen or methyl;

where  $R^1$  and  $R^2$  are independently H, an acyclic alkene comprising at least one substituent, or a cyclic ring comprising at least one substituent, wherein the cyclic ring having general structure:

20



where n is 4 to 10 carbon atoms; and

5 where W is the substituent.

871. The method of claim 870, wherein each of the substituents –W independently comprises –XR, wherein each X independently comprises O, N, or S.

10 872. The method of claim 870, wherein each of the substituents –W independently comprises amino acids, esters, carbamates, amides, carbonates, alcohol, phosphates, or sulfonates.

15 873. The method of claim 870, wherein the carotenoid derivative is at least partially water soluble.

874. The method of claim 870, wherein the substituent is at least partially hydrophilic.

20 875. The method of claim 870, further comprising increasing intercellular gap junctional communication.

876. The method of claim 870, wherein the subject is a mammal.

25 877. The method of claim 870, wherein the subject is human.

878. The method of claim 870, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally.

879. The method of claim 870, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 5 to 300 mg per day.
- 5 880. The method of claim 870, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 0.25 mg to 1.0 g per day.
- 10 881. The method of claim 870, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject.
- 15 882. The method of claim 870, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 5 to 300 mg per day.
- 20 883. The method of claim 870, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 0.25 mg to 1.0 g per day.
- 25 884. The method of claim 870, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject subcutaneously.
- 30 885. The method of claim 870, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally.
886. The method of claim 870, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 5 to 100 mg per day.



887. The method of claim 870, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 0.25 mg to 1.0 g per day.

5 888. The method of claim 870, wherein administering the carotenoid derivative to a subject comprises a dose in a range of about 0.25 mg to 1 g.

889. The method of claim 870, wherein administering the carotenoid derivative to a subject comprises at least two different carotenoid derivatives.

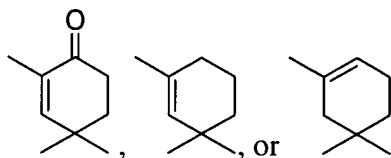
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890. The method of claim 870, wherein the cyclic ring further comprises at least one chiral center.

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891. The method of claim 870, wherein the cyclic ring further comprises at least one degree of unsaturation.

892. The method of claim 870, wherein each cyclic ring is independently

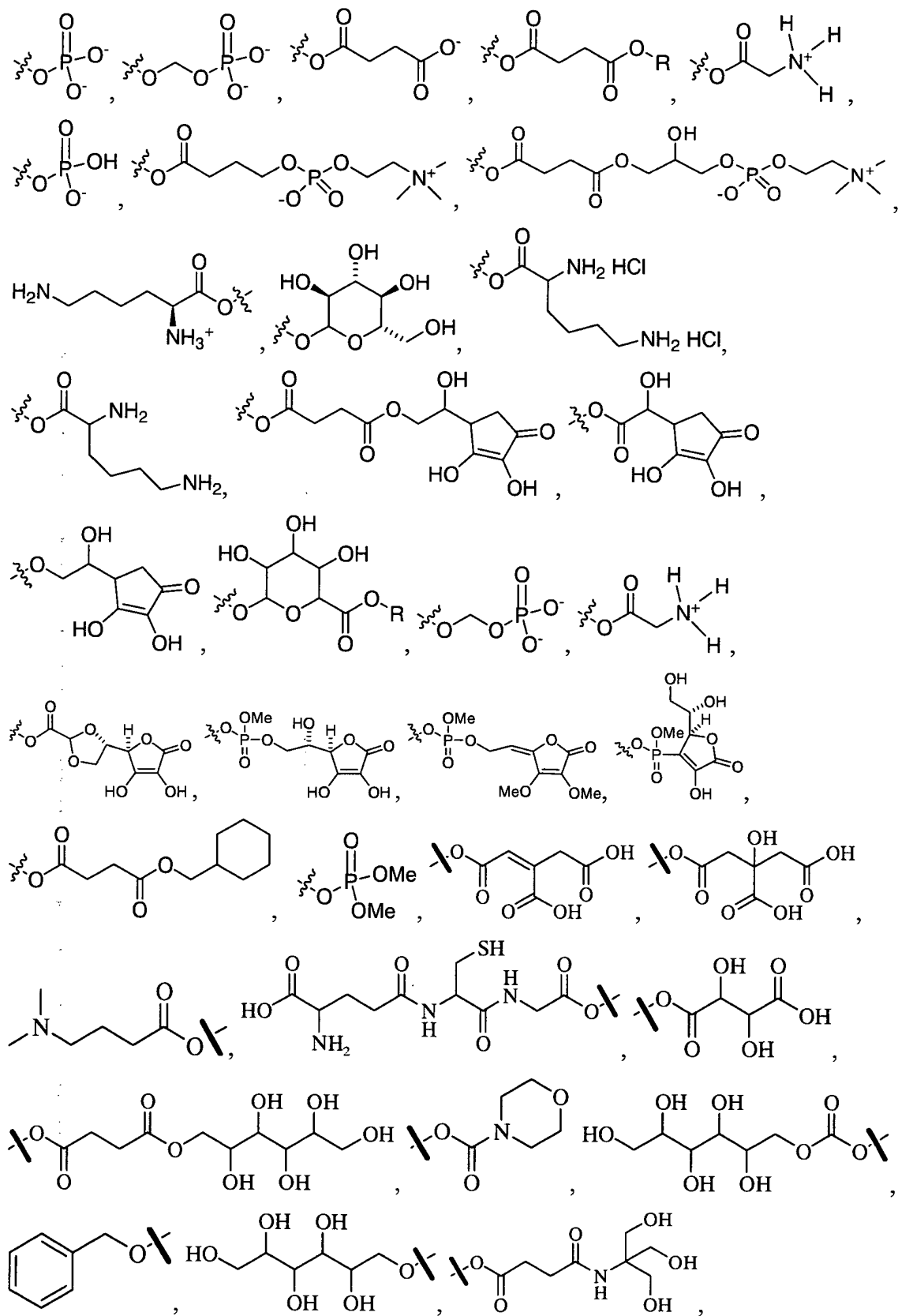


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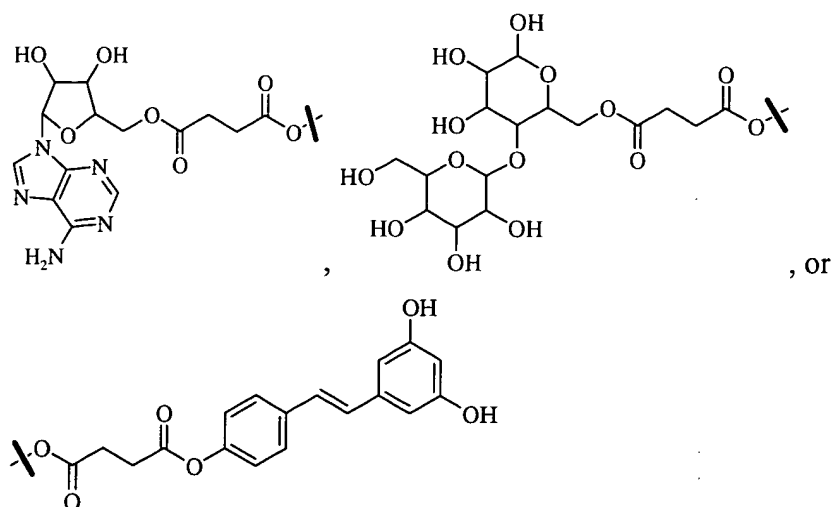
893. The method of claim 870, wherein the substituent is a carboxylic acid, an ester, an alkanol, an amine, a phosphate, a succinate, a glycinate, an ether, a glucoside, a sugar, or a carboxylate salt.

25 894. The method of claim 870, wherein each substituent is independently

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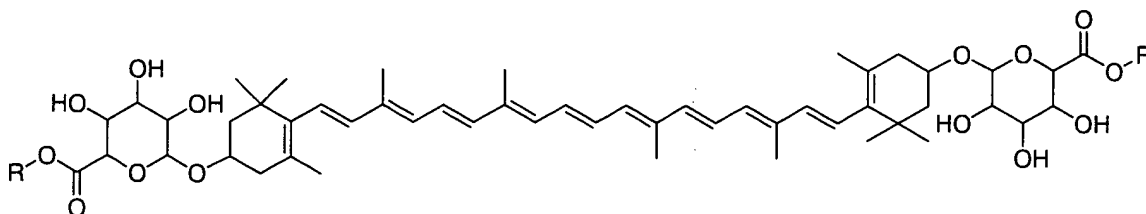


where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

895. The method of claim 870, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid.

896. The method of claim 870, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid, and wherein the naturally occurring carotenoid is lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or canthaxanthin.

897. The method of claim 870, wherein the carotenoid derivative having the structure

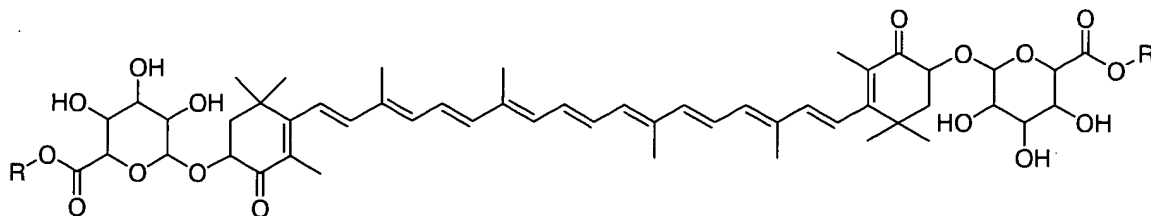


where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

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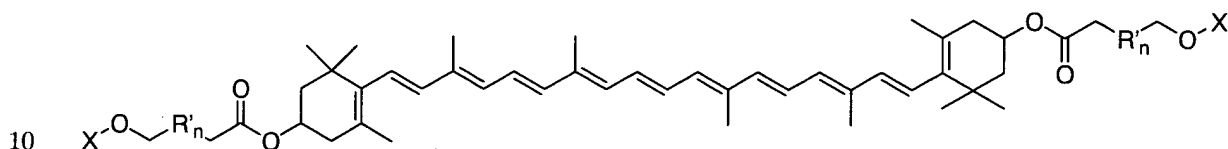
Meyertons, Hood, Kivlin,  
Kowert & Goetzel, P.C.

898. The method of claim 870, wherein the carotenoid derivative having the structure



5 where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

899. The method of claim 870, wherein the carotenoid derivative having the structure



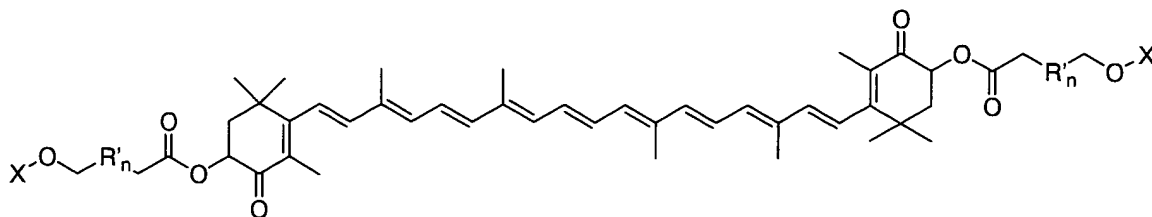
where each X is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

15

where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

20 900. The method of claim 870, wherein the carotenoid derivative having the structure

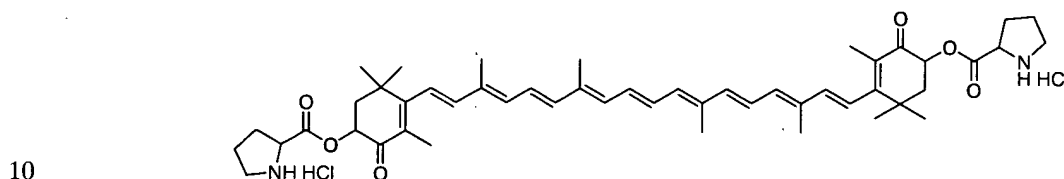


where each X is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

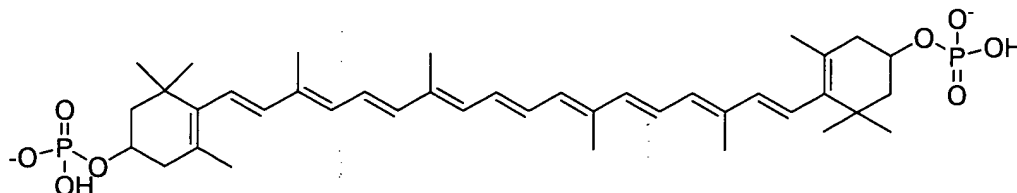
5 where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

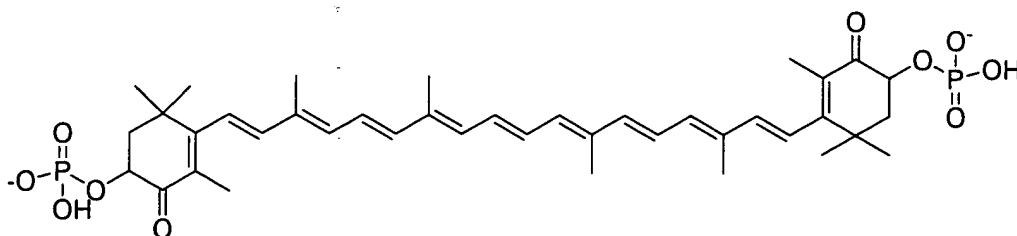
901. The method of claim 870, wherein the carotenoid derivative having the structure



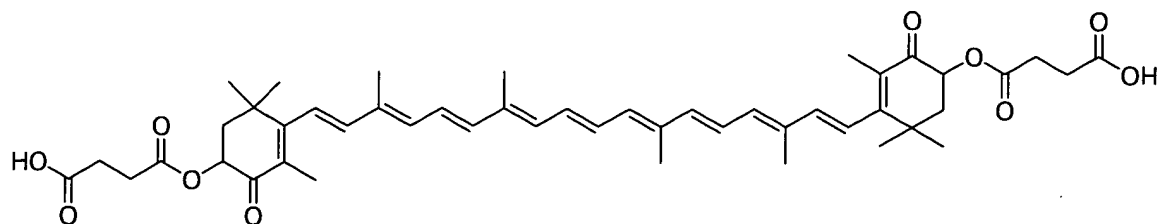
902. The method of claim 870, wherein the carotenoid derivative having the structure



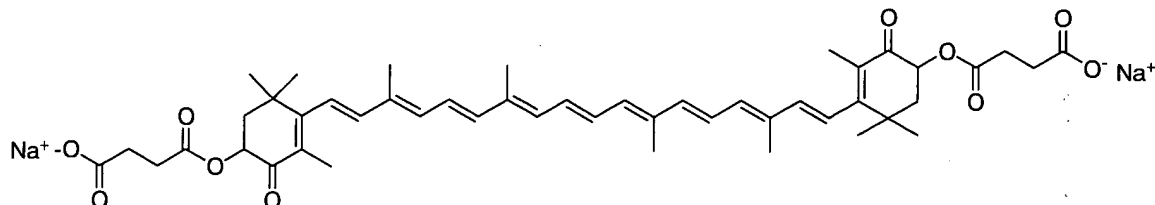
15 903. The method of claim 870, wherein the carotenoid derivative having the structure



904. The method of claim 870, wherein the carotenoid derivative having the structure

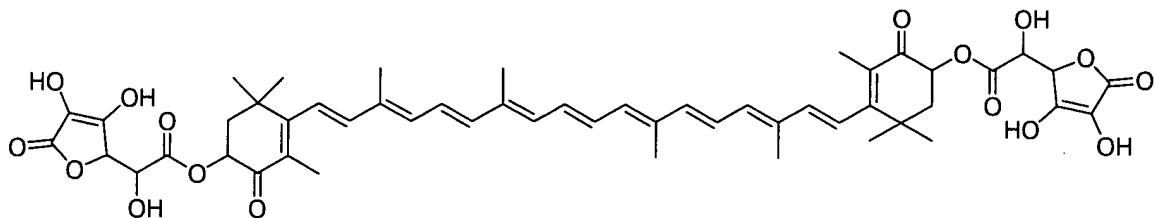


905. The method of claim 870, wherein the carotenoid derivative having the structure

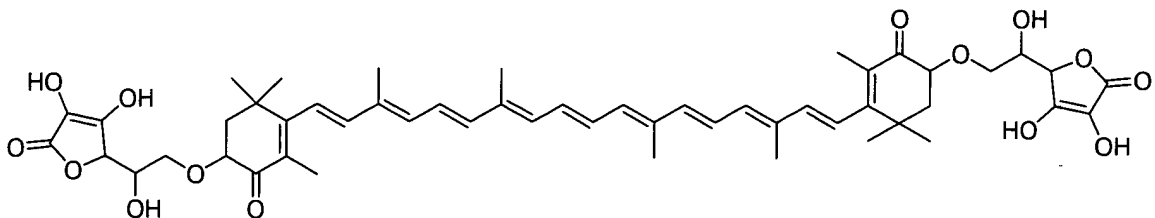


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906. The method of claim 870, wherein the carotenoid derivative having the structure

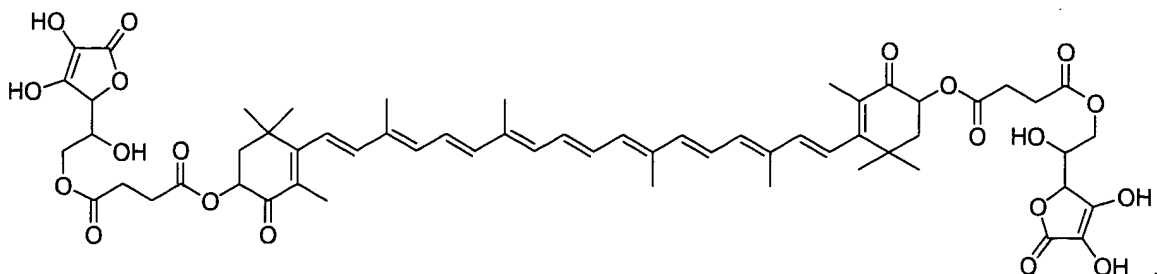


907. The method of claim 870, wherein the carotenoid derivative having the structure

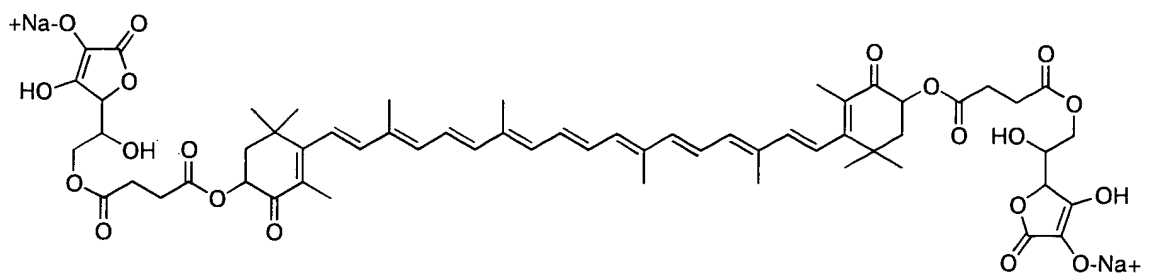


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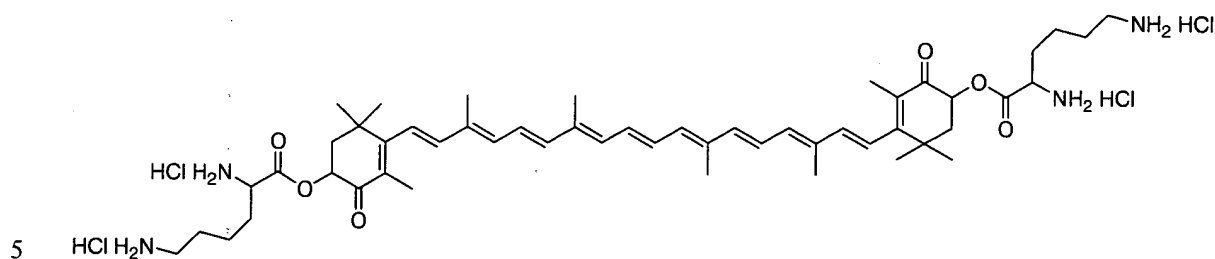
908. The method of claim 870, wherein the carotenoid derivative having the structure



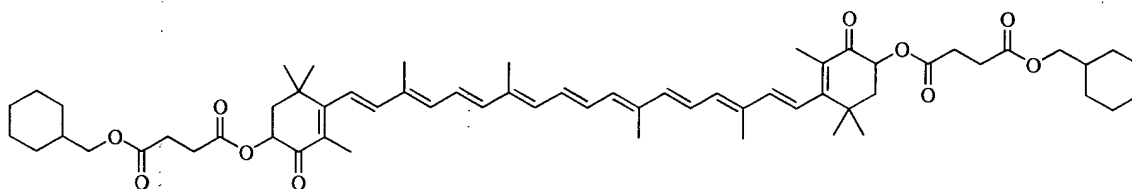
909. The method of claim 870, wherein the carotenoid derivative having the structure



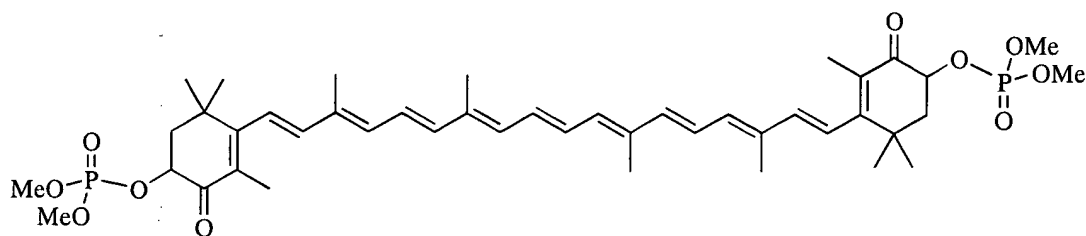
910. The method of claim 870, wherein the carotenoid derivative having the structure



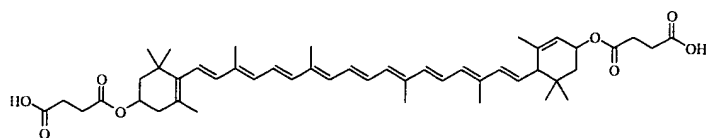
911. The method of claim 870, wherein the carotenoid derivative having the structure



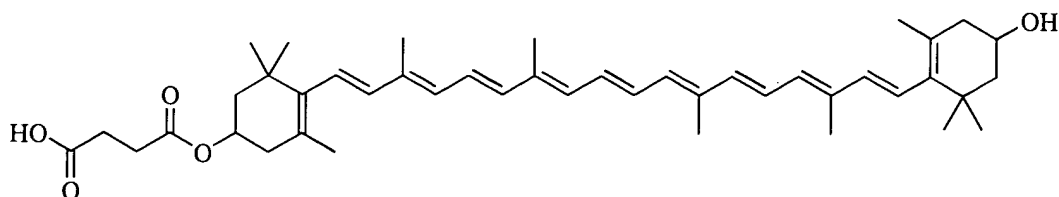
10 912. The method of claim 870, wherein the carotenoid derivative having the structure



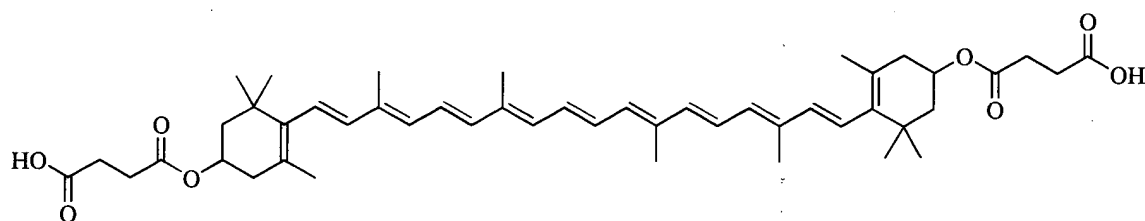
913. The method of claim 870, wherein the carotenoid derivative having the structure



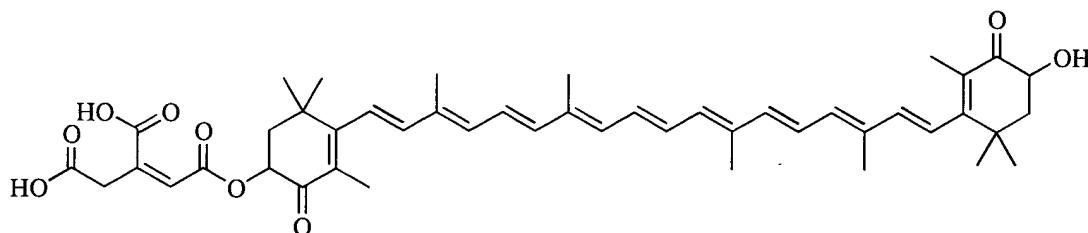
914. The method of claim 870, wherein the carotenoid derivative having the structure



5 915. The method of claim 870, wherein the carotenoid derivative having the structure

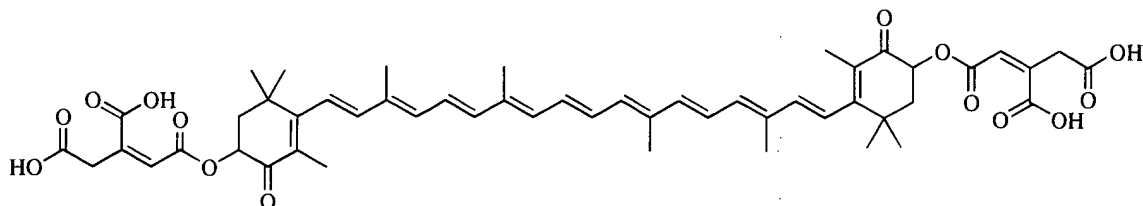


916. The method of claim 870, wherein the carotenoid derivative having the structure



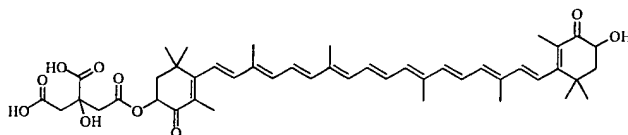
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917. The method of claim 870, wherein the carotenoid derivative having the structure

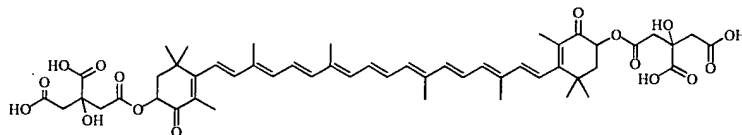


15 918. The method of claim 870, wherein the carotenoid derivative having the structure



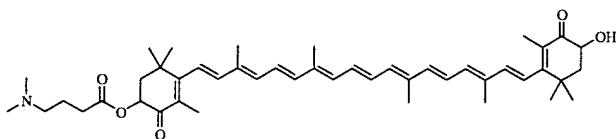


919. The method of claim 870, wherein the carotenoid derivative having the structure

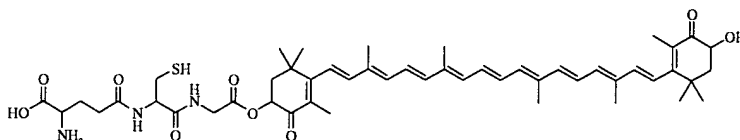


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920. The method of claim 870, wherein the carotenoid derivative having the structure

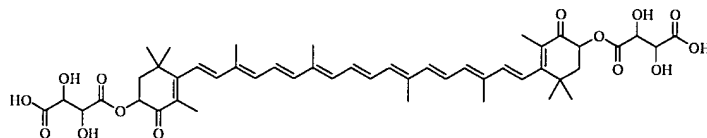


921. The method of claim 870, wherein the carotenoid derivative having the structure

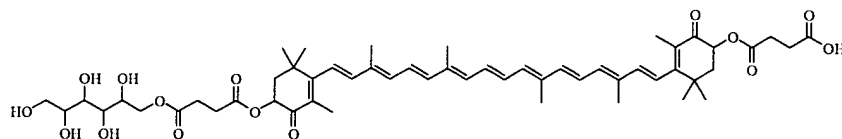


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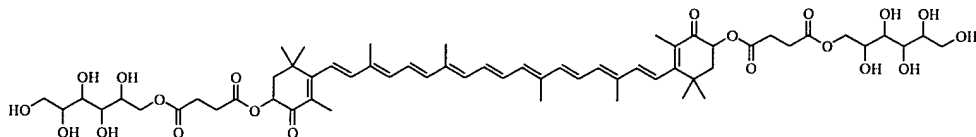
922. The method of claim 870, wherein the carotenoid derivative having the structure



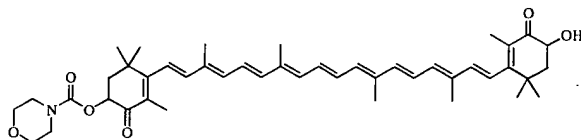
15 923. The method of claim 870, wherein the carotenoid derivative having the structure



924. The method of claim 870, wherein the carotenoid derivative having the structure

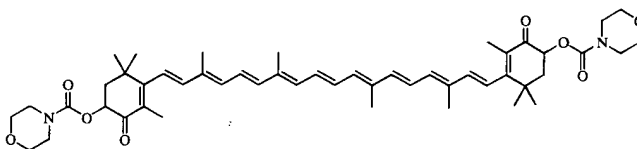


925. The method of claim 870, wherein the carotenoid derivative having the structure

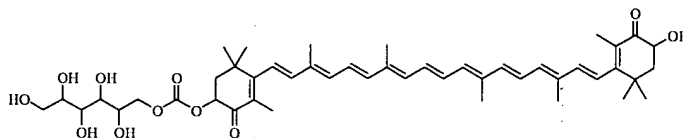


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926. The method of claim 870, wherein the carotenoid derivative having the structure

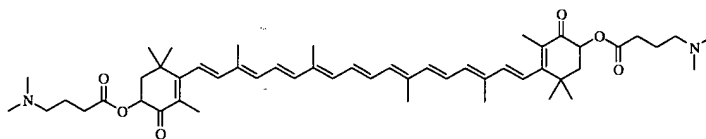


927. The method of claim 870, wherein the carotenoid derivative having the structure

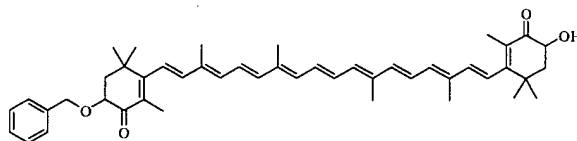


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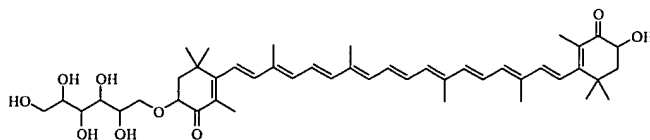
928. The method of claim 870, wherein the carotenoid derivative having the structure



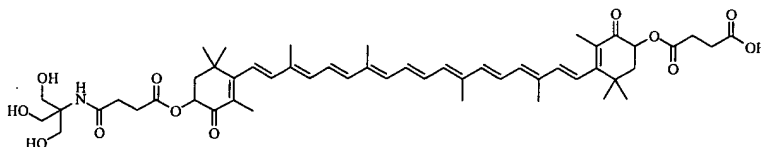
15 929. The method of claim 870, wherein the carotenoid derivative having the structure



930. The method of claim 870, wherein the carotenoid derivative having the structure

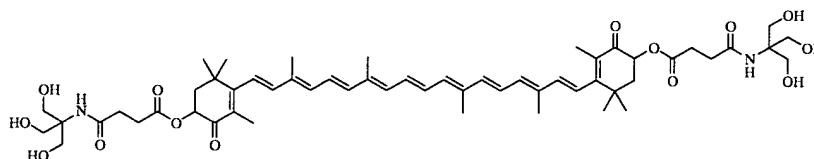


931. The method of claim 870, wherein the carotenoid derivative having the structure

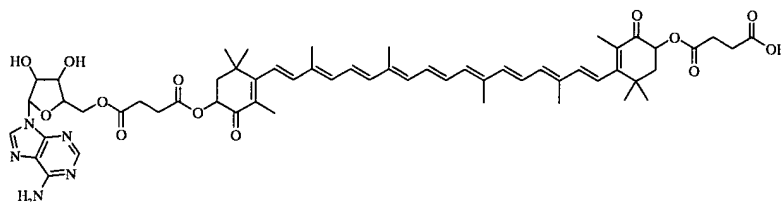


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932. The method of claim 870, wherein the carotenoid derivative having the structure

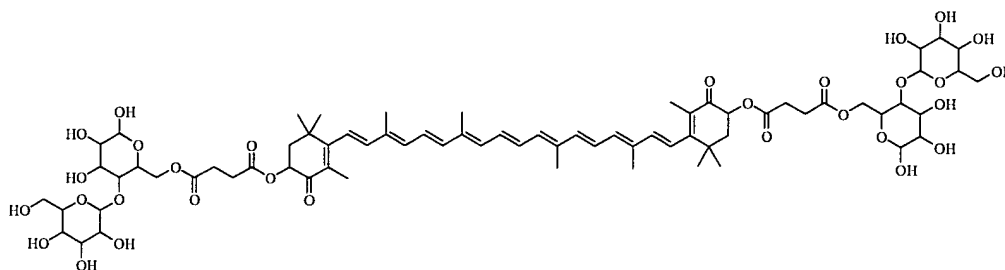


933. The method of claim 870, wherein the carotenoid derivative having the structure

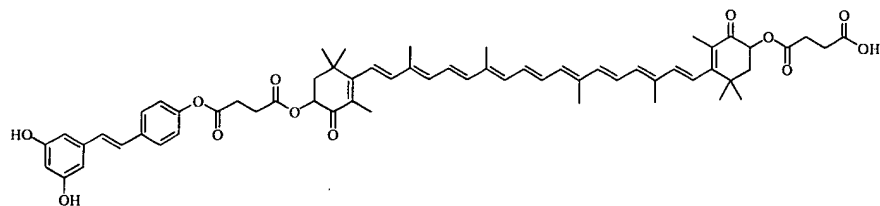


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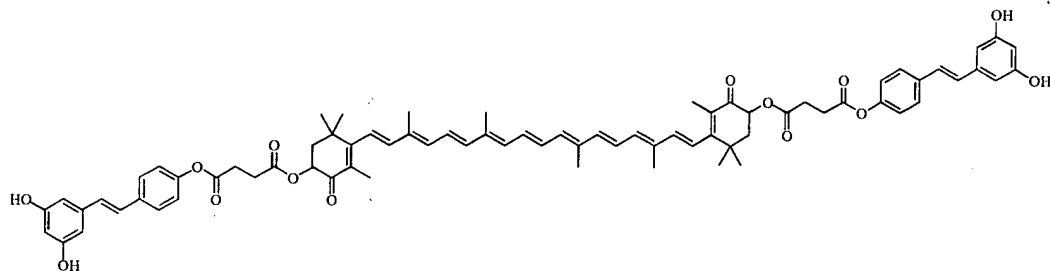
934. The method of claim 870, wherein the carotenoid derivative having the structure



15 935. The method of claim 870, wherein the carotenoid derivative having the structure



936. The method of claim 870, wherein the carotenoid derivative having the structure



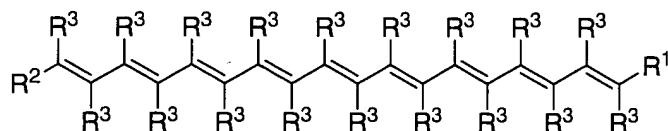
5

937. A method of treating disease with a chemical composition comprising a carotenoid derivative, comprising:

administering the carotenoid derivative to a subject;

10

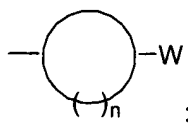
wherein the carotenoid derivative has the structure



15

where each  $R^3$  is independently hydrogen or methyl;

where  $R^1$  and  $R^2$  are independently H, an acyclic alkene comprising at least one substituent, or a cyclic ring comprising at least one substituent, wherein the cyclic ring having general structure:



20

where n is 4 to 10 carbon atoms; and

where W is the substituent;

5

wherein the disease produces reactive oxygen species.

10

938. The method of claim 937, wherein each of the substituents –W independently comprises –XR, wherein each X independently comprises O, N, or S.

939. The method of claim 937, wherein each of the substituents –W independently comprises amino acids, esters, carbamates, amides, carbonates, alcohol, phosphates, or sulfonates.

15

940. The method of claim 937, wherein the carotenoid derivative is at least partially water soluble.

941. The method of claim 937, wherein the substituent is at least partially hydrophilic.

20

942. The method of claim 937, further comprising increasing intercellular gap junctional communication.

25

943. The method of claim 937, wherein the disease comprises age-related macular degeneration (ARMD), retinal detachment, hypertensive retinal disease, uveitis, choroiditis, vitreitis, ocular hemorrhage, degenerative retinal damage, cataractogenesis, cataracts, retinopathy of prematurity, Meunier's disease, drug-induced ototoxicity, infectious otitis, idiopathic otitis, otitis media, infectious sinusitis, allergic sinusitis, or head and neck cancer.

30

944. The method of claim 937, wherein the disease comprises senile dementia, Alzheimer's disease, Neuman-Pick's disease, neurotoxin reactions, hyperbaric

5 oxygen effects, Parkinson's disease, cerebral trauma, spinal cord trauma,  
hypertensive cerebrovascular injury, stroke, infectious encephalitis, meningitis,  
allergic encephalomyelitis, multiple sclerosis, neuronal ceroid lipofuscinoses,  
ataxia-telangiectasia syndrome, metal overload, amyotrophic lateral sclerosis  
(ALS), primary brain carcinoma/malignancy, or brain metastases.

945. The method of claim 937, wherein the disease comprises arteriosclerosis,  
atherosclerosis, peripheral vascular disease, myocardial infarction, inflammatory  
10 heart disease, cardiomyopathies, cardiac arrhythmia, drug toxicity, Keshan  
disease, trypanosomiasis, or alcohol cardiomyopathy, chronic stable angina,  
unstable angina, idiopathic surgical injury during CABG and/or PTCA, elevated  
C-reactive protein (CRP), myeloperoxidase (MPO), low-density lipoprotein  
oxidation (ox-LDL), congestive heart failure (CHF), venous stasis and injury,  
deep venous thrombosis (DVT), or thrombophlebitis.

15 946. The method of claim 937, wherein the disease comprises asthma, reactive airways  
disease, chronic obstructive pulmonary disease, hyperoxia, hyperbaric oxygen  
effects, cigarette smoke inhalation effects, environmental oxidant pollutant  
effects, acute respiratory distress syndrome, bronchopulmonary dysplasia, mineral  
20 dust pneumoconiosis, adriamycin toxicity, bleomycin toxicity, paraquat, chemical  
pneumonitis, idiopathic pulmonary interstitial fibrosis, infectious pneumonia,  
sarcoidosis, asbestosis, small- and large-cell lung cancer, anthrax infection, or  
anthrax toxin exposure.

25 947. The method of claim 937, wherein the disease comprises hypertensive renal  
disease, end-stage renal disease, diabetic renal disease, infectious  
glomerulonephritis, nephrotic syndrome, allergic glomerulonephritis, type I-IV  
hypersensitivity reactions, renal allograft rejection, nephritic antiglomerular  
basement membrane disease, heavy metal nephrotoxicity, drug-induced  
30 nephrotoxicity, rhabdomyolysis, or renal carcinoma.

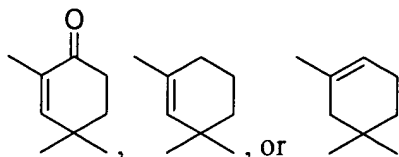
- 5 948. The method of claim 937, wherein the disease comprises carbon tetrachloride liver injury, endotoxin liver injury, lipopolysaccharide liver injury, chronic viral infection, hemachromatosis, Wilson's disease, acetaminophen overdose, congestive heart failure with hepatic congestion, alcoholic cirrhosis, idiopathic cirrhosis, hepatocellular carcinoma, or hepatic metastatic carcinoma.
- 10 949. The method of claim 937, wherein the disease comprises inflammatory bowel disease, Crohn's disease, ulcerative colitis, irritable bowel syndrome, colon carcinoma, polyposis, infectious diverticulitis, toxic megacolon, gastritis, *Helicobacter pylori* infection, gastric carcinoma, esophagitis, Barrett's esophagus, gastro-esophageal reflux disease (GERD), Whipple's disease, gallstone disease, cholecystitis, pancreatitis, abetalipoproteinemia, infectious gastroenteritis, dysentery, or non-steroidal anti-inflammatory drug-induced toxicity.
- 15 950. The method of claim 937, wherein the disease comprises lead poisoning, drug-induced bone-marrow suppression, protoporphyrin photo-oxidation, lymphoma, leukemia, porphyria, parasitic infection, malaria, sickle cell anemia, thalassemia, favism, pernicious anemia, Fanconi's anemia, post-infectious anemia, idiopathic thrombocytopenic purpura, or autoimmune deficiency syndromes (AIDS).
- 20 951. The method of claim 937, wherein the disease comprises infectious prostatitis, prostate carcinoma, prostate carcinoma in-situ, benign prostatic hypertrophy (BPH), urethritis, orchitis, testicular torsion, cervicitis, cervical carcinoma, ovarian carcinoma, uterine carcinoma, vaginitis, or vaginismus.
- 25 952. The method of claim 937, wherein the disease comprises osteoarthritis, rheumatoid arthritis, tendonitis, muscular dystrophy, degenerative disc disease, degenerative joint disease, exercise-induced skeletal muscle injury, carpal tunnel syndrome, Guillan-Barre syndrome, Paget's disease of bone, ankylosing
- 30 spondylitis, or heterotopic bone formation.

- 5
953. The method of claim 937, wherein the disease comprises solar radiation injury, sunburn, thermal injury, chemical and contact dermatitis, Rhus dermatitis, psoriasis, Bloom syndrome, leukoplakia, infectious dermatitis, or Kaposi's sarcoma.
954. The method of claim 937, wherein the reactive oxygen species comprise radicals.
955. The method of claim 937, wherein the subject is a mammal.
- 10 956. The method of claim 937, wherein the subject is human.
957. The method of claim 937, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally.
- 15 958. The method of claim 937, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 5 to 300 mg per day.
- 20 959. The method of claim 937, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject parenterally at a dose of about 0.25 mg to 1.0 g per day.
- 25 960. The method of claim 937, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject.
- 30 961. The method of claim 937, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 5 to 300 mg per day.



962. The method of claim 937, wherein administering the carotenoid derivative to a subject comprises intracoronary administration of the carotenoid derivative to a subject at a dose of about 0.25 mg to 1.0 g per day.
- 5 963. The method of claim 937, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject subcutaneously.
- 10 964. The method of claim 937, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally.
965. The method of claim 937, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 5 to 100 mg per day.
- 15 966. The method of claim 937, wherein administering the carotenoid derivative to a subject comprises administering the carotenoid derivative to a subject orally at a dose of about 0.25 mg to 1.0 g per day.
- 20 967. The method of claim 937, wherein administering the carotenoid derivative to a subject comprises a dose in a range of about 0.25 mg to 1 g.
968. The method of claim 937, wherein administering the carotenoid derivative to a subject comprises at least two different carotenoid derivatives.
- 25 969. The method of claim 937, wherein the cyclic ring further comprises at least one chiral center.
970. The method of claim 937, wherein the cyclic ring further comprises at least one degree of unsaturation.
- 30

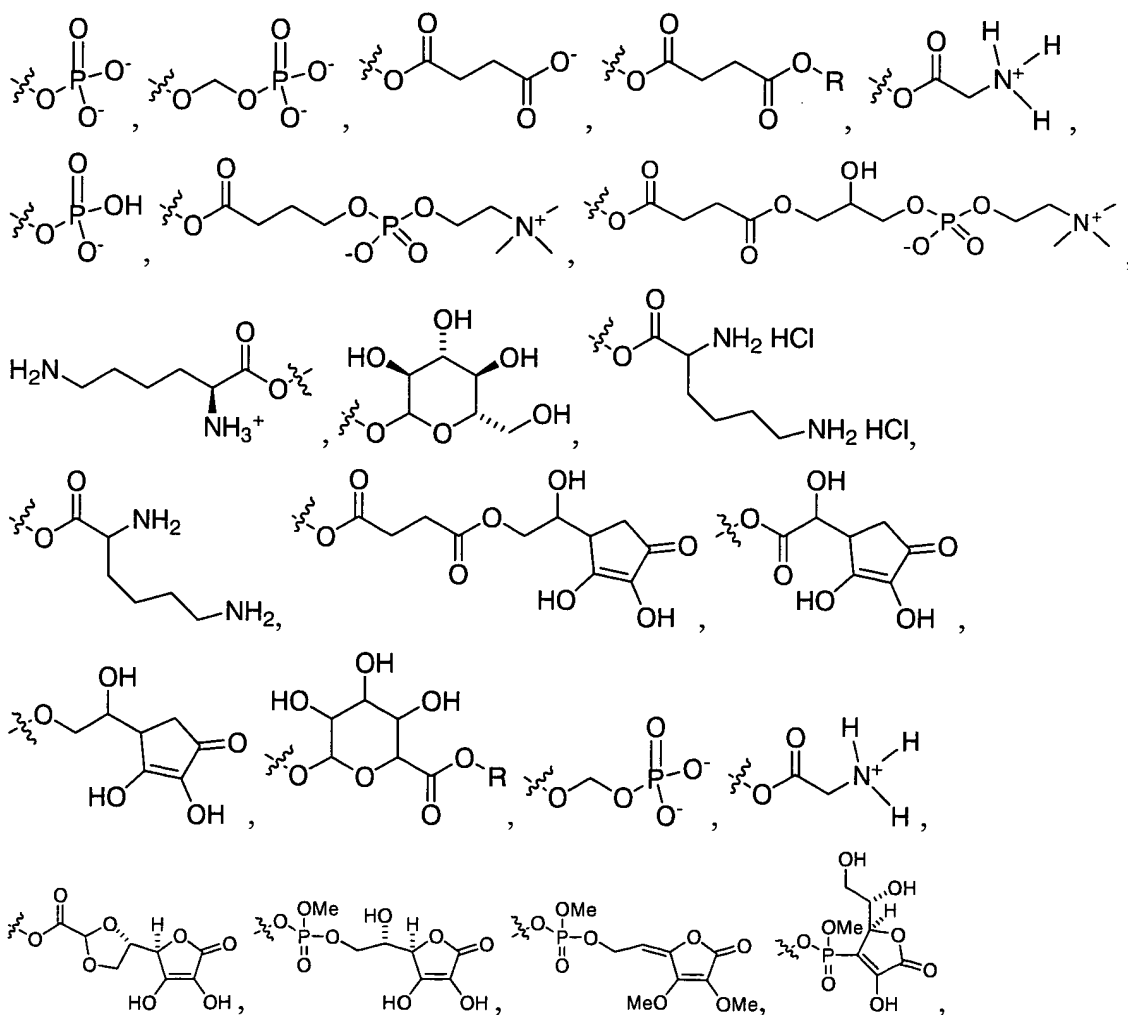
971. The method of claim 937, wherein each cyclic ring is independently



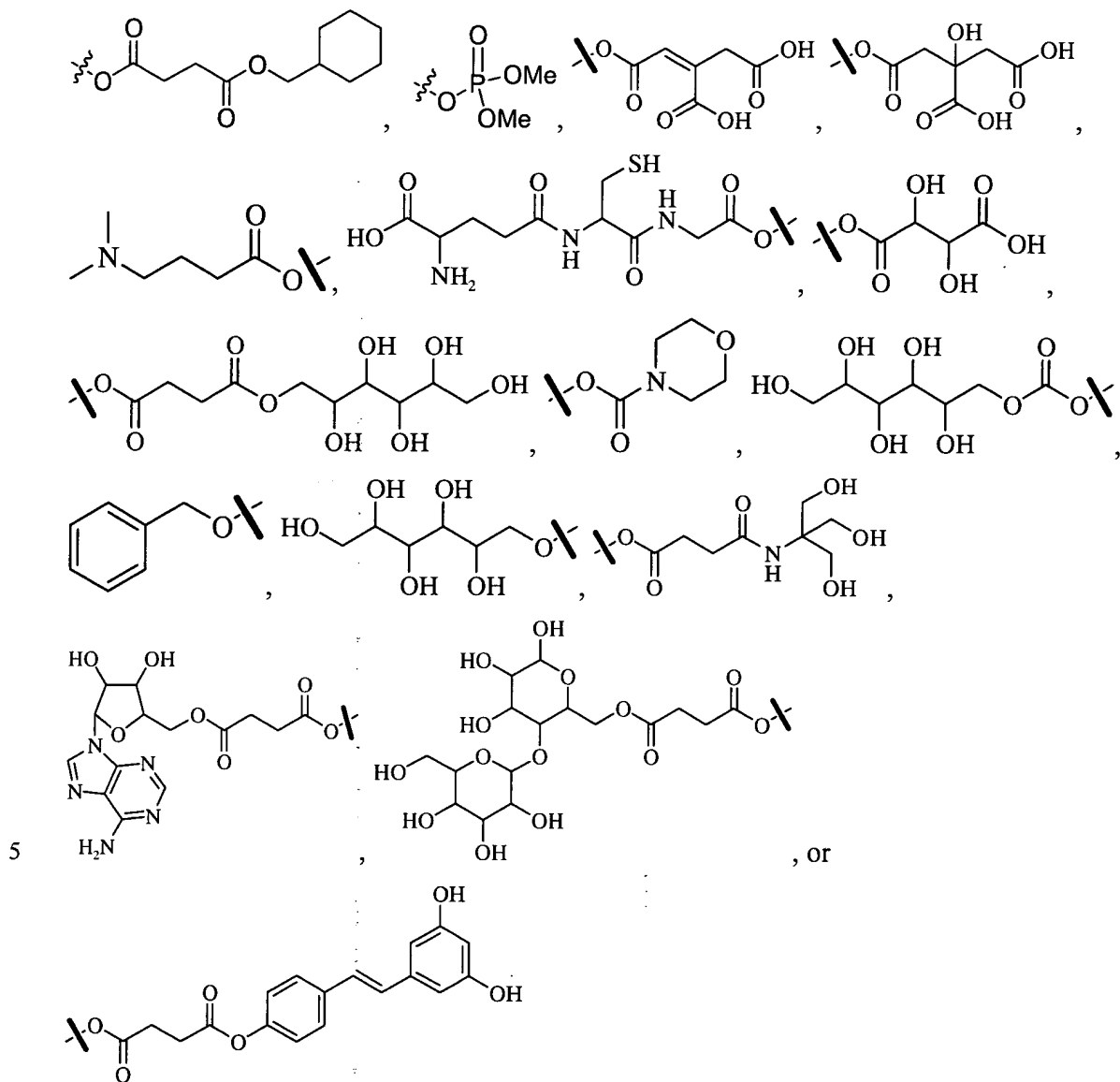
972. The method of claim 937, wherein the substituent is a carboxylic acid, an ester, an alkanol, an amine, a phosphate, a succinate, a glycinate, an ether, a glucoside, a sugar, or a carboxylate salt.

973. The method of claim 937, wherein each substituent is independently

10



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where each R is independently -alkyl-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -aromatic-NR<sup>1</sup><sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

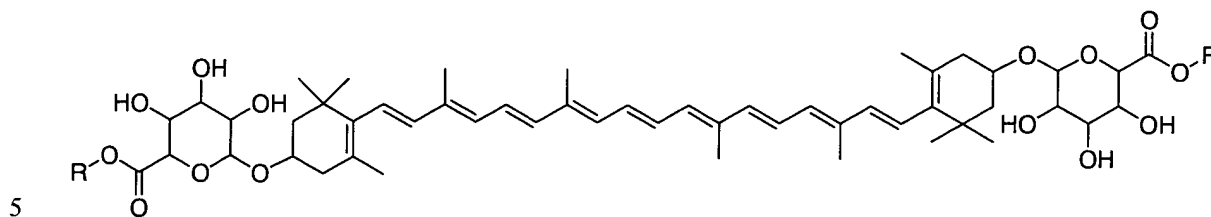
974. The method of claim 937, wherein the carotenoid derivative is a derivative of a naturally occurring carotenoid.

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Meyertons, Hood, Kivlin,  
Kowert & Goetzel, P.C.

lycopene, lycophyll, lycozanthin, astaxanthin, beta-carotene, lutein, zeaxanthin, or canthaxanthin.

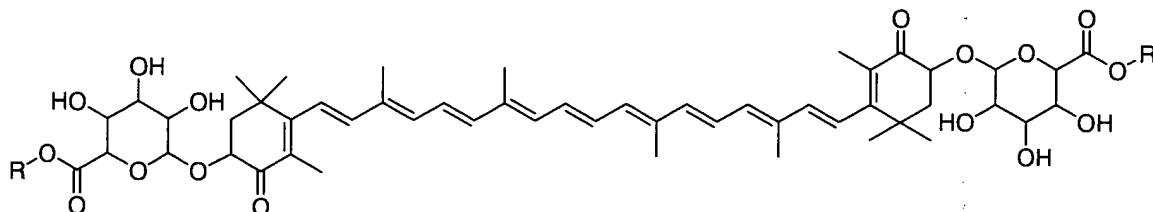
976. The method of claim 937, wherein the carotenoid derivative having the structure



where each R is independently -alkyl-NR<sub>3</sub><sup>+</sup>, -aromatic-NR<sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

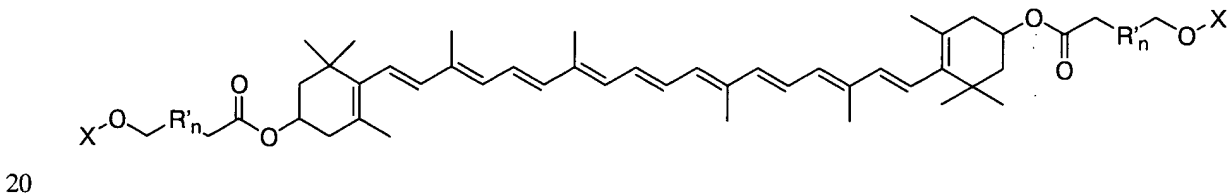
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977. The method of claim 937, wherein the carotenoid derivative having the structure



15 where each R is independently -alkyl-NR<sub>3</sub><sup>+</sup>, -aromatic-NR<sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl.

978. The method of claim 937, wherein the carotenoid derivative having the structure



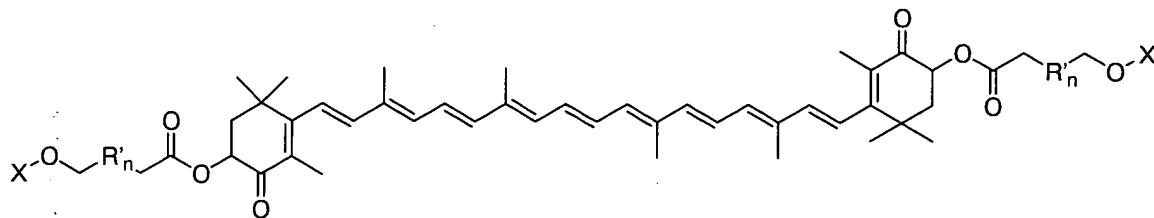
where each X is independently -alkyl-NR<sub>3</sub><sup>+</sup>, -aromatic-NR<sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

where each R' is independently -alkyl-O, alkyl, or aryl; and

where n is between about 0 and 12.

5

979. The method of claim 937, wherein the carotenoid derivative having the structure



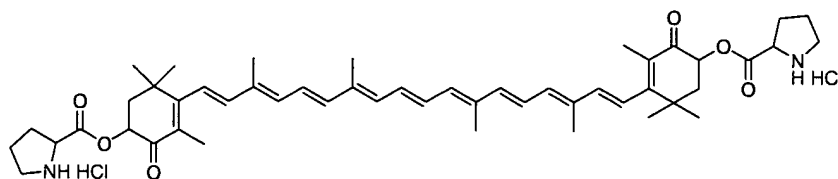
where each X is independently -alkyl-NR<sub>3</sub><sup>+</sup>, -aromatic-NR<sub>3</sub><sup>+</sup>, -alkyl-CO<sub>2</sub><sup>-</sup>, -aromatic-CO<sub>2</sub><sup>-</sup>, -amino acid-NH<sub>3</sub><sup>+</sup>, -phosphorylated amino acid-NH<sub>3</sub><sup>+</sup>, polyethylene glycol, dextran, H, alkyl, or aryl;

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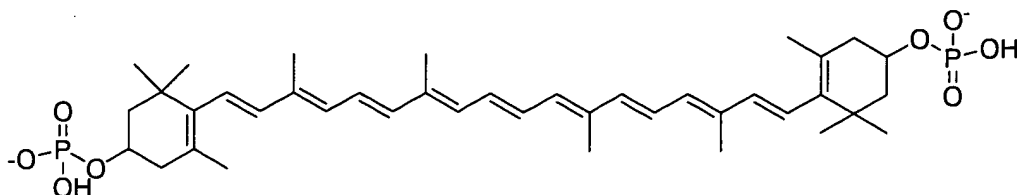
where each R' is independently -alkyl-O, alkyl, or aryl; and

15 where n is between about 0 and 12.

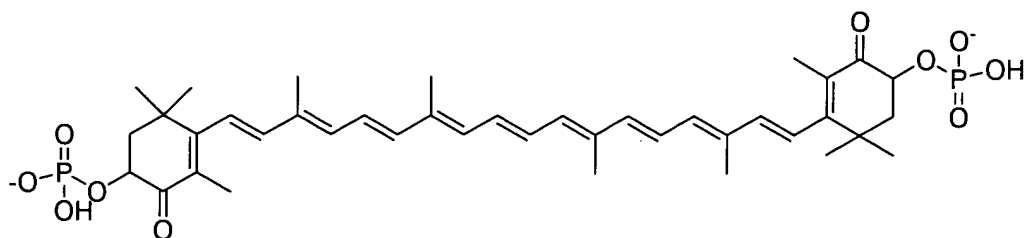
980. The method of claim 937, wherein the carotenoid derivative having the structure



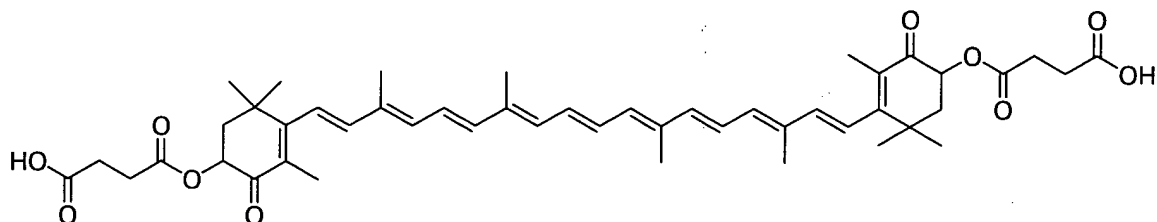
20 981. The method of claim 937, wherein the carotenoid derivative having the structure



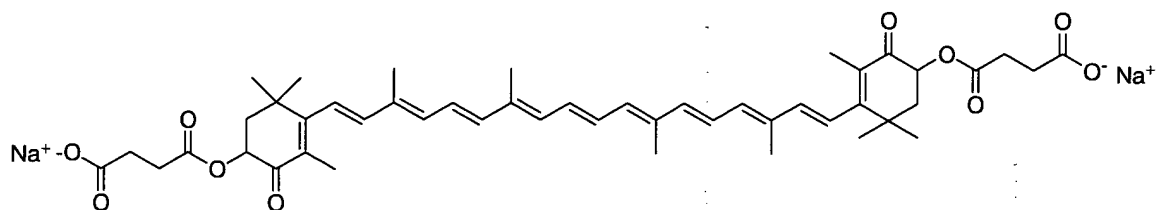
982. The method of claim 937, wherein the carotenoid derivative having the structure



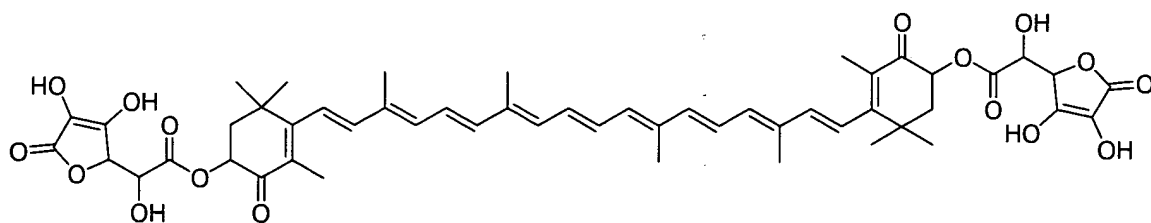
983. The method of claim 937, wherein the carotenoid derivative having the structure



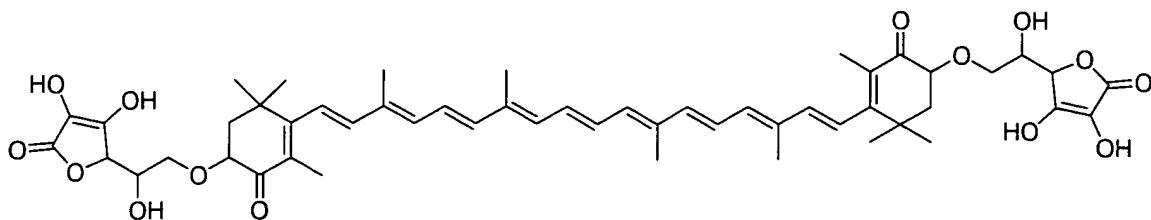
984. The method of claim 937, wherein the carotenoid derivative having the structure



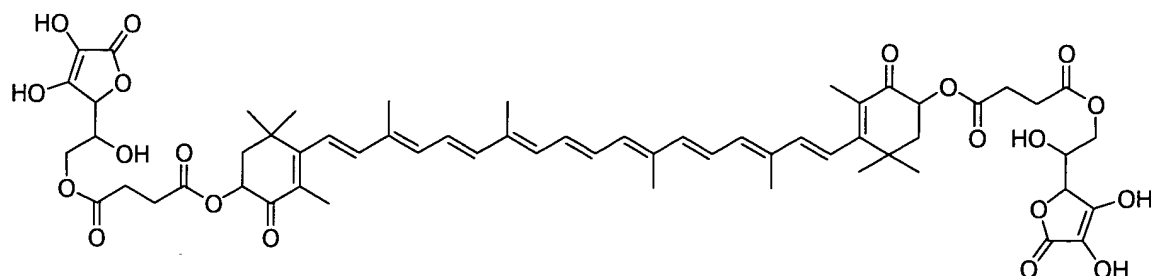
985. The method of claim 937, wherein the carotenoid derivative having the structure



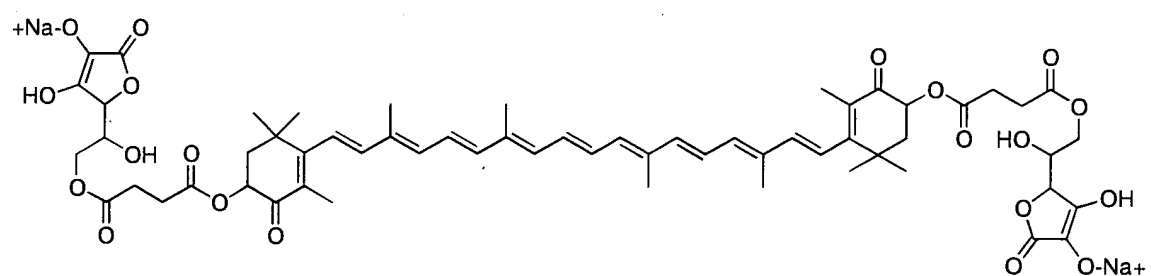
986. The method of claim 937, wherein the carotenoid derivative having the structure



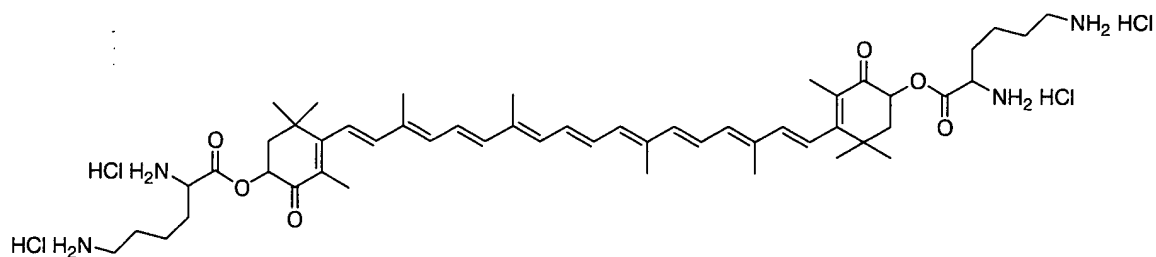
987. The method of claim 937, wherein the carotenoid derivative having the structure



5 988. The method of claim 937, wherein the carotenoid derivative having the structure

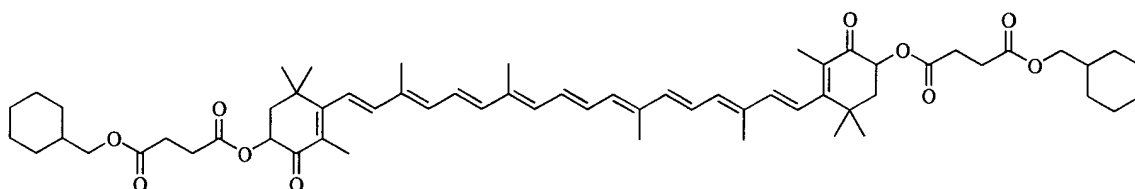


989. The method of claim 937, wherein the carotenoid derivative having the structure

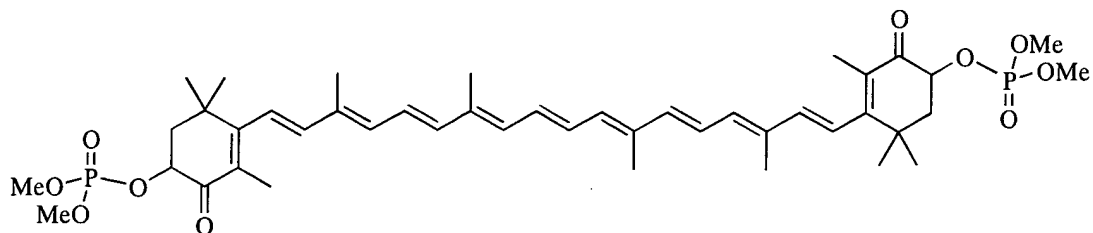


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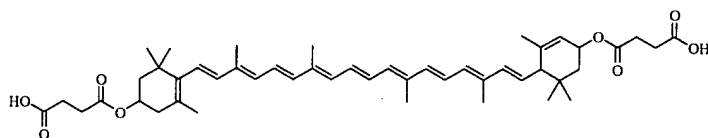
990. The method of claim 937, wherein the carotenoid derivative having the structure



991. The method of claim 937, wherein the carotenoid derivative having the structure

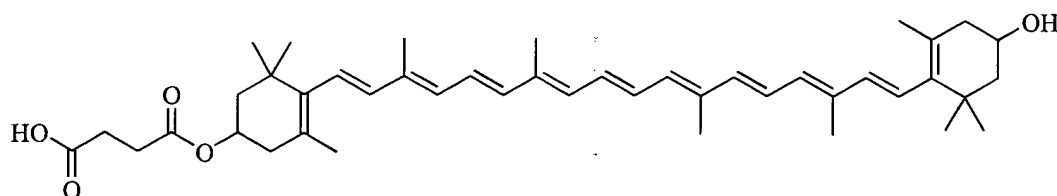


992. The method of claim 937, wherein the carotenoid derivative having the structure



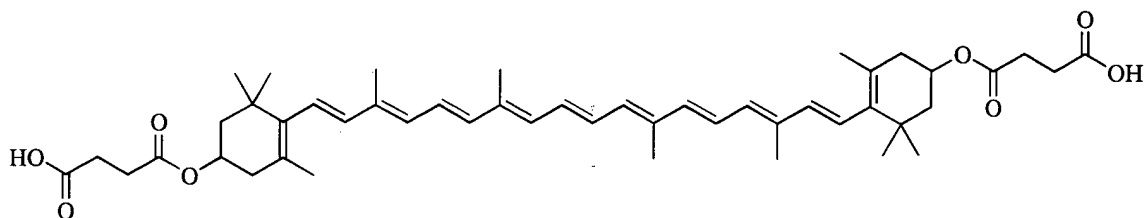
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993. The method of claim 937, wherein the carotenoid derivative having the structure

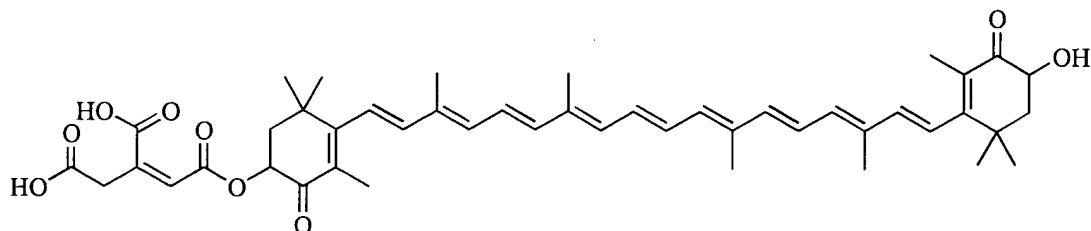


994. The method of claim 937, wherein the carotenoid derivative having the structure

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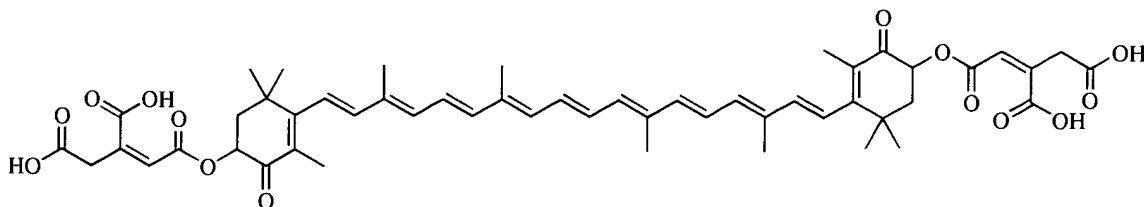
995. The method of claim 937, wherein the carotenoid derivative having the structure



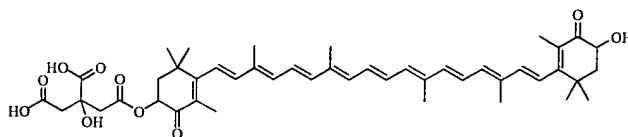
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996. The method of claim 937, wherein the carotenoid derivative having the structure

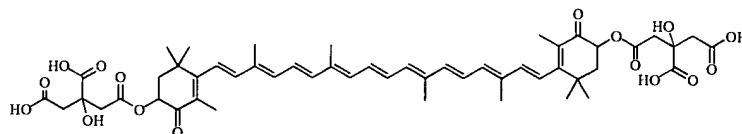


997. The method of claim 937, wherein the carotenoid derivative having the structure

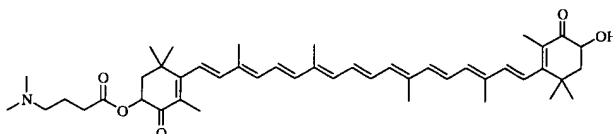


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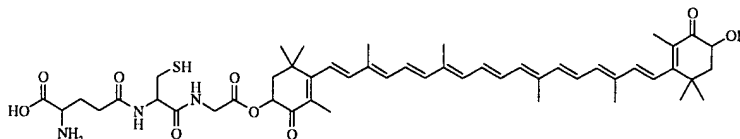
998. The method of claim 937, wherein the carotenoid derivative having the structure



10 999. The method of claim 937, wherein the carotenoid derivative having the structure

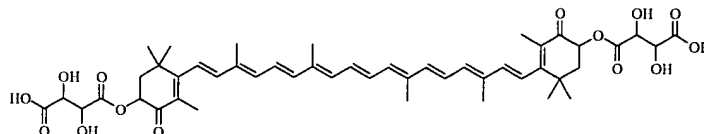


1000. The method of claim 937, wherein the carotenoid derivative having the structure

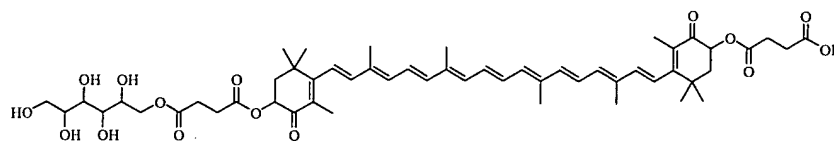


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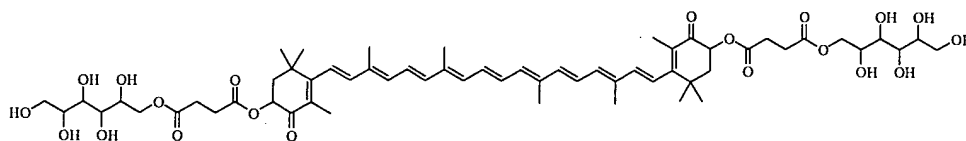
1001. The method of claim 937, wherein the carotenoid derivative having the structure



1002. The method of claim 937, wherein the carotenoid derivative having the structure

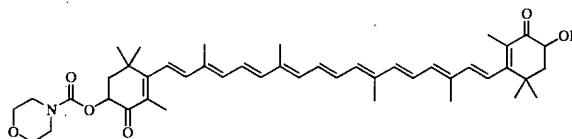


1003. The method of claim 937, wherein the carotenoid derivative having the structure

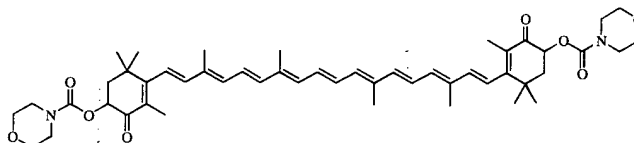


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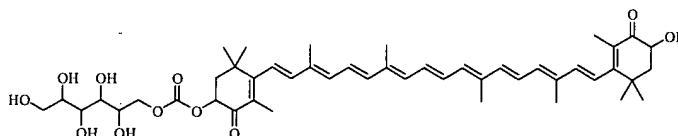
1004. The method of claim 937, wherein the carotenoid derivative having the structure



10 1005. The method of claim 937, wherein the carotenoid derivative having the structure

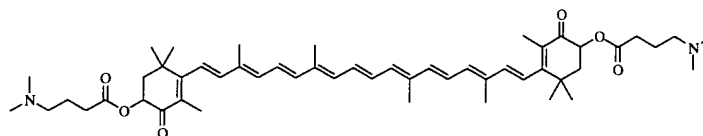


1006. The method of claim 937, wherein the carotenoid derivative having the structure

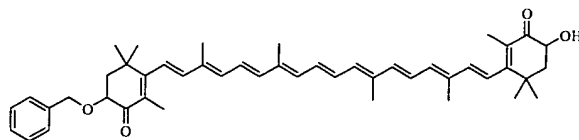


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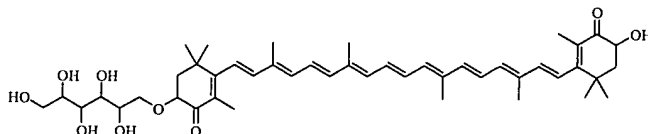
1007. The method of claim 937, wherein the carotenoid derivative having the structure



1008. The method of claim 937, wherein the carotenoid derivative having the structure

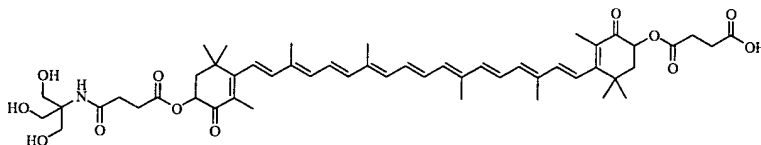


1009. The method of claim 937, wherein the carotenoid derivative having the structure

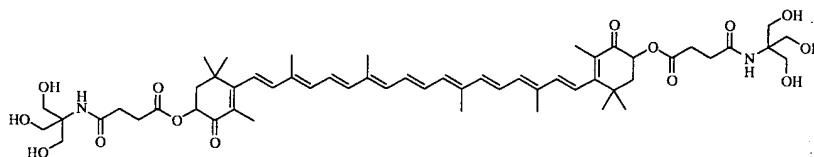


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1010. The method of claim 937, wherein the carotenoid derivative having the structure

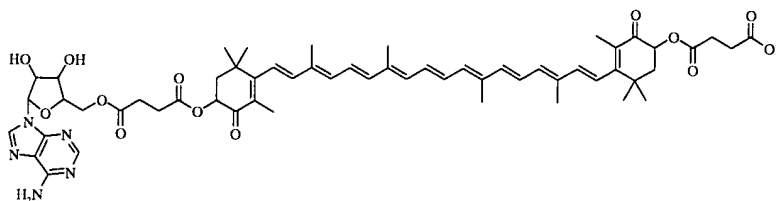


1011. The method of claim 937, wherein the carotenoid derivative having the structure

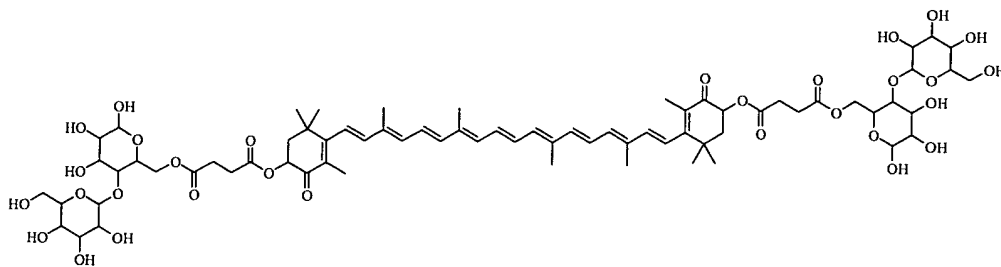


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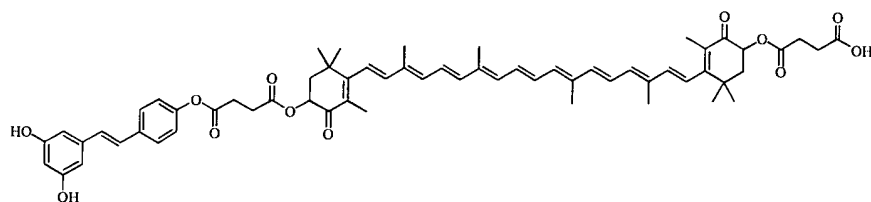
1012. The method of claim 937, wherein the carotenoid derivative having the structure



15 1013. The method of claim 937, wherein the carotenoid derivative having the structure

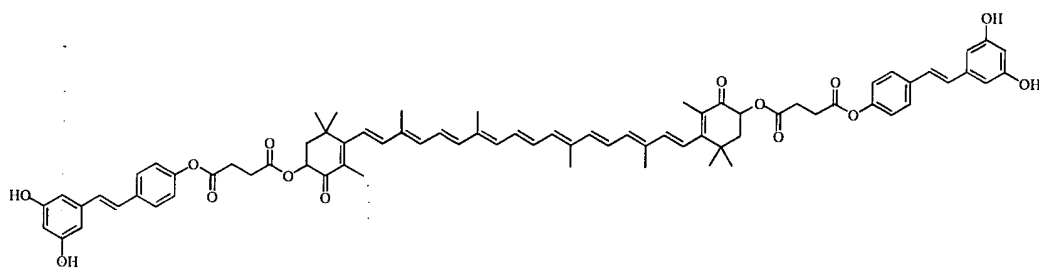


1014. The method of claim 937, wherein the carotenoid derivative having the structure



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1015. The method of claim 937, wherein the carotenoid derivative having the structure



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